Ontario

Ministry of the Environment

Ontario Drinking Water Standards

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1. ONTARIO DRINKING WATER STANDARDS, OBJECTIVES AND GUIDELINES

1.1 Introduction

The Ontario Drinking Water Standards are established to assist with meeting the legislated requirements governing water works under the Ontario Water Resources Act (OWRA) and should be used in conjunction with the Drinking Water Protection Regulation.

The primary purpose of the Ontario Drinking Water Standards is to protect public health through the provision of safe drinking water. Water intended for human consumption shall not contain disease-causing organisms or unsafe concentrations of toxic chemicals or radioactive substances. Water should also be aesthetically acceptable. Taste, odour, turbidity and colour are parameters that, when controlled, result in water which is clear, colourless and without objectionable or unpleasant taste or odour. Other aspects of water quality such as corrosiveness, a tendency to form incrustations and excessive soap consumption should be controlled on the basis of economic considerations because of their effects on the distribution system and/or the intended domestic and industrial use of the water.

Parameters and their associated standards and objectives are listed alphabetically in Tables 1 through 4. A brief description is provided for these parameters in Appendix A. Some parameters, which do not have specific objectives, are listed because there is an ideal condition or range for them in terms of water treatment plant operation or aesthetic water quality.

Section 4 is devoted to sampling protocol, examination of drinking water supplies, and the required corrective actions to be taken when a standard is exceeded. A discussion of water disinfection is outlined in Appendix B.

1.2 Types of standards and objectives

Standards/objectives are considered to be the minimum level of quality and in no way should be regarded as implying that allowing the degradation of a high quality water supply to the specified level or range is acceptable. The standards and objectives described herein have been derived from the best information currently available, however, setting standards and objectives is a continual process. Society continues to introduce new chemicals and microorganisms into the environment that have a potential to contaminate drinking water supplies. Standards and objectives are reviewed as new and more significant data becomes available. Criteria used to evaluate the safety of drinking water are continually reassessed as new parameters are identified and health effects research advances. The water supply industry is developing new and improved operation and treatment techniques to respond to the changing criteria. Drinking water quality criteria must consider all factors that affect the quality of water, the public health significance of the parameters and the available technology to treat water.

This document addresses the following types of **standards:**

Maximum Acceptable Concentration (MAC)

The MAC is a health-related standard established for parameters which when present above a certain concentration, have known or suspected adverse health effects. The length of time the MAC can be exceeded without injury to health will depend on the nature and concentration of the parameter.

Interim Maximum Acceptable Concentration (IMAC)

The IMAC is a health-related standard established for parameters either when there are insufficient toxicological data to establish a MAC with reasonable certainty, or when it is not feasible, for practical reasons, to establish a MAC at the desired level.

This document addresses the following types of **objectives:**

Aesthetic Objective (AO)

AOs are established for parameters that may impair the taste, odour or colour of water or which may interfere with good water quality control practices. For certain parameters, both aesthetic objectives and health-related MACs have been derived.

Operational Guidelines (OG)

OGs are established for parameters that need to be controlled to ensure efficient and effective treatment and distribution of the water.

1.3 Application of standards/objectives/guidelines

In carrying out its responsibilities under section 52 of the OWRA, the MOE applies the Ontario Drinking Water Standards in approving the establishment of any water works, or the extension of or change in any existing water works capable of supplying water at a rate greater than 50,000 litres per day or water works that supply drinking water to more than five private residences.

2. WATER WORKS

2.1 Source protection, treatment and operations

The water supply should be obtained from a source that is most likely to produce drinking water of a quality meeting the Ontario Drinking Water Standards and Policies. The source chosen should be one least subject to municipal and/or industrial pollution, as well as other types of pollution resulting from

human activities within the watershed. The continuous presence of a parameter at a level in excess of a MAC or IMAC may be grounds for rejection of the water unless effective and economic treatment is available. Chemical parameters should not be present in a water supply above their AO values where other more suitable supplies are or can be made available at a reasonable cost.

The owner of the water works should conduct frequent surveys of impacts of pollution on the water source. Each survey should attempt to recognize all potential sources of pollution of the water supply.

Some water quality changes occur naturally in surface waters as a result of sunlight as well as physical and biological processes. With ground water, natural purification may occur by infiltration of the water through soil and percolation through underlying material. Effective treatment should be provided to ensure safety and consistency in the quality of the drinking water.

Minimum treatment levels of surface waters and ground waters for drinking water are stated in the Drinking Water Protection Regulation. Deviation from the disinfection requirement for groundwater supplies may be permitted on a case-by-case basis in accordance with the Drinking Water Protection Regulation. In some cases additional treatment processes may be required to produce a drinking water that consistently meets the requirements of Ontario Drinking Water Standards.

The following items can assist in protecting public health:

- treatment processes that are appropriate for the source of supply;
- a water works with adequate capacity, within established design guidelines, to meet maximum demands;
- a water works designed, located and constructed to minimize the effects of pollution at the raw water intake and to prevent contamination or disruption of the supply during high or low water conditions; and
- water works operators who are licensed and classified in accordance with Ontario Regulation 435/93 Water Works and Sewage Works.

2.2 Approval of water works

Construction of new water works or alterations, replacement or extensions to existing works may proceed only after a Director under the Act has issued an Approval, under Section 52, of the OWRA. The decision for granting approval of water works is based on:

- adequate quantity and satisfactory quality of the water source based on the Ontario Drinking Water Standards and Policies;
- adequate treatment facilities to consistently produce water that meets standards/objectives and requirements as set out in this document;

- adequate capacity to meet peak demands without development of low pressures in the distribution system that could result in health hazards;
- sound engineering principles;
- ability to comply with relevant policies and guidelines; and
- public interest considerations.

The assessment of the raw water quality available from the proposed source of supply should be supported by a sufficient number of physical, chemical and bacteriological analyses of raw water samples obtained from the proposed source.

For a ground water source, it is usually sufficient to base the suitability of the source water on several samples obtained during the well pumping tests conducted to establish the yield of the well(s). In order to establish a reliable data base for a surface water source, it is generally necessary to undertake a water sampling and analysis survey extending over sufficiently long period of time to account for seasonal variations in the water quality.

Normally, the source water analyses should include all physical, chemical and bacteriological parameters identified in Tables 1 through 4. However, where general knowledge and/or historical data indicate that, in the proposed water source, particular substances (e.g. radionuclides) are consistently absent or below the level of concern, these substances/parameters need not be included in the analyses, provided that such an elimination has been agreed to, in writing, by the MOE.

Note: The terms and conditions of the Certificate of Approval specify performance, monitoring and reporting as site-specific legally enforceable requirements.

2.3 Responsibility for water quality

In general, the municipality that distributes the drinking water is responsible for its quality. Where a third party is contracted for the treatment and/or distribution of water, it acts as a statutory agent for the appropriate municipality, and the municipality therefore remains ultimately responsible for ensuring that water of adequate quality is delivered to consumers. The owner shall ensure that a protocol is established for the purpose of notification and corrective action. Private owners and operators of water works subject to the provisions of the OWRA are fully responsible for the quality of water delivered to the consumer.

Table 1 - Chemical/Physical Standards and Objectives (mg/L)			
PARAMETER	MAC	IMAC	AO
Alachlor		0.005	
Aldicarb	0.009		
Aldrin + Dieldrin	0.0007		
Arsenic		0.025	
Atrazine + N-dealkylated metabolites		0.005	
Azinphos-methyl	0.02		
Barium	1.0		
Bendiocarb	0.04		
Benzene	0.005		
Benzo(a)pyrene	0.00001		
Boron		5.0	
Bromoxynil		0.005	
Cadmium	0.005		
Carbaryl	0.09		
Carbofuran	0.09		
Carbon Tetrachloride	0.005		
Chloramines	3.0		
Chlordane (Total)	0.007		
Chlorpyrifos	0.09		
Chromium	0.05		
Cyanazine		0.01	
Cyanide	0.2		
Diazinon	0.02		
Dicamba	0.12		
1,2-Dichlorobenzene	0.2		0.003
1,4-Dichlorobenzene	0.005		0.001
Dichlorodiphenyltrichloroethane	0.03		
1,2-dichloroethane		0.005	
1,1-Dichloroethylene(vinylidene chloride)	0.014		

Table 1 - Chemical/Physical Standards and Objectives (mg/L)			
PARAMETER	MAC	IMAC	AO
Dichloromethane	0.05		
2-4-Dichlorophenol	0.9		0.0003
2,4-Dichlorophenoxy acetic acid(2,4-D)		0.1	
Diclofop-methyl	0.009		
Dimethoate		0.02	
Dinoseb	0.01		
Dioxin and Furan		0.000000015 [a]	
Diquat	0.07		
Diuron	0.15		
Fluoride	1.5 [b]		
Glyphosate		0.28	
Heptachlor + Heptachlor Epoxide	0.003		
Lead	0.01 [c]		
Lindane (Total)	0.004		
Malathion	0.19		
Mercury	0.001		
Methoxychlor	0.9		
Metolachlor		0.05	
Metribuzin	0.08		
Monochlorobenzene	0.08		0.03
Nitrate (as nitrogen)	10.0 [d]		
Nitrite (as nitrogen)	1.0 [d]		
Nitrate + Nitrite (as nitrogen)	10.0 [d]		
Nitrilotriacetic Acid (NTA)	0.4		
Nitrosodimethylamine (NDMA)		0.000009	
Paraquat		0.01	
Parathion	0.05		
Pentachlorophenol	0.06		0.03
Phorate		0.002	
Picloram		0.19	

Table 1 - Chemical/Physical Standards and Objectives (mg/L)			
PARAMETER	**MAC**	**IMAC**	**AO**
Polychlorinated Biphenyls (PCB)		0.003	
Prometryne		0.001	
Selenium	0.01		
Simazine		0.01	
Temephos		0.28	
Terbufos		0.001	
Tetrachloroethylene (perchloroethylene)	0.030		
2,3,4,6-Tetrachlorophenol	0.10		0.001
Triallate	0.23		
Trichloroethylene	0.05		
2,4,6-Trichlorophenol	0.005		0.002
2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	0.28		0.02
Trifluralin		0.045	
Trihalomethanes	0.100 [e]		
Turbidity	1.0 [f]		5.0 [f]
Uranium	0.10		
Vinyl Chloride	0.002		

Notes on Table 1:

Short forms:
MAC - Maximum Acceptable Concentration
NTU - Nephelometric Turbidity Unit
IMAC - Interim Maximum Acceptable Concentration
mg/L - milligrams per litre
AO - Aesthetic Objective

Footnotes:

a) Total toxic equivalents when compared with 2,3,7,8-TCDD (tetrachlorodibenzo-p-dioxin).
b) Where fluoride is added to drinking water, it is recommended that the concentration be adjusted to 1.0(+/- 0.2) mg/L the optimum level for control of tooth decay. Where supplies contain naturally occurring fluoride at levels higher than 1.5 mg/L but less than 2.4 mg/L the

Ministry of Health and Long Term Care recommends an approach through local boards of health to raise public and professional awareness to control excessive exposure to fluoride from other sources. Levels above the MAC must be reported to the local Medical Officer of Health.

c) This standard applies to water at the point of consumption. Since lead is a component in some plumbing systems, first flush water may contain higher concentrations of lead than water that has been flushed for five minutes.

d) Where both nitrate and nitrite are present, the total of the two should not exceed 10 mg/L (as nitrogen).

e) This standard is expressed as a running annual average of quarterly samples measured at a point reflecting the maximum residence time in the distribution system.

f) A MAC for turbidity of 1.0 NTU in drinking water leaving the treatment plant was established to ensure the efficiency of the disinfection process. Distribution system protection processes can result in increased turbidity in the distribution system. To ensure that the aesthetic quality is not degraded, an aesthetic objective for turbidity at the free flowing outlet of the ultimate consumer has been set at 5 NTU.

Table 2 - Microbiological Standards - Health Related

PARAMETERS	**MAC (per 100 ml)**
Total Coliforms	see Section 4.2.2
Escherichia coli and/or Fecal Coliforms*	not detected
General Bacterial Population**	see Section 4.2.2

Footnotes:

* *Escherichia coli* is a more definitive indicator of fecal contamination than fecal coliforms or total coliforms.

** At elevated levels, the general bacterial population may interfere with the detection of coliforms. This general population can be estimated from either background colony counts on the total coliform membrane filters or heterotrophic plate counts (HPC).

Table 3- Radionuclide Standards - Health Related					
Natural Radionuclides					
Parameter	MAC(Bq/L	Parameter	MAC(Bq/L	Parameter	MAC (Bq/L)
Beryllium-7	4000	Radium-226	0.6	Thorium-234	20
Bismuth -210	70	Radium-228	0.5	Uranium-234	4
Lead-210	0.1	Thorium-228	2	Uranium-235	4
Polonium-210	0.2	Thorium-230	0.4	Uranium-238	4
Radium-224	2	Thorium-232	0.1		
Artificial Radionuclides					
Parameter	MAC(Bq/L	Parameter	MAC(Bq/L	Parameter	MAC (Bq/L)
Americium-241	0.2	Iodine-125	10	Selenium-75	70
Antimony-122	50	Iodine-129	1	Silver-108m	70
Antimony-124	40	Iodine-131	6	Silver-110m	50
Antimony-125	100	Iron-55	300	Silver-111	70
Barium-140	40	Iron-59	40	Sodium-22	50
Bromine-82	300	Manganese-54	200	Strontium-85	300
Calcium-45	200	Mercury-197	400	Strontium-89	40
Calcium-47	60	Mercury-203	80	Strontium-90	5
Carbon-14	200	Molybdenum-99	70	Sulphur-35	500
Cerium-141	100	Neptunium-239	100	Technetium-99	200
Cerium-144	20	Nibium-95	200	Technetium-99m	7000
Cesium-131	2000	Phosphorus-32	50	Tellurium-129m	40
Cesium-134	7	Plutonium-238	0.3	Tellurium-131m	40
Cesium-136	50	Plutonium-239	0.2	Tellurium-132	40
Cesium-137	10	Plutonium-240	0.2	Thallium-201	2000
Chromium-51	3000	Plutonium-241	10	Tritium	7000
Cobalt-57	40	Rhodium-105	300	Ytterbium-169	100
Cobalt-58	20	Rubidium-81	3000	Yttrium-90	30
Cobalt-60	2	Rubidium-86	50	Yttrium-91	30
Gallium-67	500	Ruthenium-103	100	Zinc-65	40
Gold-198	90	Ruthenium-106	10	Zirconium-95	100
Indium-111	400				

Notes on Table 3:

Radionuclide concentrations that exceed the MAC may be tolerated for a short duration, provided that the annual average concentrations remain below the MAC and the restriction (see immediately below) for multiple radionuclides is met.

Restrictions for multiple radionuclides - If two or more radionuclides are present, the following relationship based on International Commission on Radiological Protection (ICRP) Publication 26, must be satisfied and if not satisfied, it shall be considered to be exceedence of an MAC.

$$\frac{c_1}{C_1} + \frac{c_2}{C_2} + \ldots\ldots\ldots\ldots\ldots\ldots \frac{c_i}{C_i} \leq 1$$

where c_1, c_2, and c_i are the observed concentrations, and C_1, C_2 and C_i are the maximum acceptable concentrations for each contributing radionuclide.

Table 4 - Chemical/Physical Objectives (mg/L) - Not Health Related		
Parameter	**Objective**	**Type of Objective**
Alkalinity (as $CaCO_3$)	30-500	OG
Aluminum	0.10	OG
Chloride	250	AO
Colour	5 TCU	AO
Copper	1.0	AO
Dissolved Organic Carbon	5.0	AO
Ethylbenzene	0.0024	AO
Hardness (as $CaCO_3$)	80-100	OG
Iron	0.30	AO
Manganese	0.05	AO
Methane	3L/ m^3	AO
Odour	Inoffensive	AO
Organic Nitrogen	0.15	OG
pH	6.5-8.5 (no units)	OG
Sodium	a	AO
Sulphate	500 [b]	AO
Sulphide	0.05	AO
Taste	Inoffensive	AO
Temperature	15°C	AO
Toluene	0.024	AO
Total Dissolved Solids	500	AO
Xylenes	0.30	AO
Zinc	5.0	AO

AO - Aesthetic Objective OG - Operational Guideline TCU - True Colour Units

Footnotes:

g) The aesthetic objective for sodium in drinking water is 200 mg/L. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

h) When sulphate levels exceed 500 mg/L, water may have a laxative effect on some people.

3. WATER QUALITY CHARACTERISTICS

Parameters that contribute to the characteristics of drinking water are categorized as either health related or aesthetic. Health related parameters are a concern for acute and/or chronic exposure, whereas parameters that affect taste and odour, or which cause operational problems are aesthetic. Parameters affecting the quality of water are characterized as microbiological, chemical, physical or radiological.

The limits for chemical or physical health related parameters are listed as standards in Table 1. Microbiological standards are listed in Table 2 and standards for radionuclides are listed in Table 3. Aesthetic objectives are listed in both Tables 1and 4. These parameters are discussed in Appendix A.

3.1 Health-related characteristics

3.1.1 Microbiological characteristics

The microbiological quality of drinking water is the most important aspect of drinking water quality because of its association with waterborne diseases. Typhoid fever, cholera, enteroviral disease, bacillary and amoebic dysenteries, and many varieties of gastrointestinal diseases, can all be transmitted by water. Limits for viruses and protozoa are not proposed at this time, however, it is desirable that no virus or protozoa (e.g. *giardia, cryptosporidium*) be present in drinking water.

The introduction of a well managed water treatment system with effective chemically-assisted filtration and disinfection, an adequately maintained chlorine residual in the distribution system and the implementation of bacteriological surveillance programs to ensure the delivery of safe drinking water are measures that have demonstrated their effectiveness in eliminating water-related illnesses. Occasional outbreaks of waterborne diseases emphasize the importance of continuing the strict supervision and control over the microbiological quality of drinking water.

3.1.2 Chemical characteristics

Certain chemicals are potentially toxic and may adversely affect human health. Heavy metals and substances such as cyanide, some commonly occurring organic compounds and many less common organic and organometallic parameters are potentially hazardous in drinking water. It is desirable to control the intake of these potentially toxic chemicals from drinking water because the intake from other sources such as milk, food or air may be difficult to avoid. MACs or IMACs have been set for those toxic chemical parameters that could be present at significant levels in drinking water. In general, total environmental exposure, food intake, and possible adverse effects from long-term exposure have been taken into consideration in deriving the standard. The aim of setting standards for contaminants is to avoid undesirable health effects.

Inorganic parameters may be present in water naturally or as a result of industrial, urban, or agricultural activities or other discharges.

Organic parameters are present to some degree in all municipal water supplies. Industrial and municipal waste, urban and agricultural run-off, and the natural decomposition of biological matter all contribute to the organic content. Some organic chemicals occur in water naturally as a result of organic decomposition. Synthetic organic chemicals can also be present in drinking water as a result of certain water treatment practices and/or direct contamination of the raw water from point and non-point sources of pollution. Most synthetic organic chemicals detected in drinking water are present at low concentrations and do not appear to pose a health threat.

Drinking water should be free of pesticides, and every effort should be made to prevent pesticides from entering raw water sources.

3.1.3 Physical characteristics

The physical characteristics of water traditionally include colour, odour, taste, temperature and turbidity. Although these are primarily aesthetic parameters, they can have indirect effects on health through interrelationships with health related parameters. For example, temperature affects the rate of growth of microorganisms, while some colour-producing and naturally occurring organic parameters are trihalomethane precursors. To date, turbidity is the only physical characteristic for which there are sufficient data to establish a limit on the basis of health considerations.

3.1.4 Radioactive characteristics

There are more than 200 radionuclides. Some occur naturally while others are products from human activities such as mining, nuclear energy production, nuclear weapons testing and manufacturing.

Ingestion of radionuclides in drinking water may cause cancer in individuals exposed and heritable genetic changes in their children. The probability of inducing such effects is assumed to be proportional to the radiation doses delivered to sensitive organs and tissues. It is assumed that no threshold exists below which the probability of induced effects is zero.

In Ontario, MACs have been set for radionuclide concentrations to protect consumers of drinking water from unacceptable risks. In keeping with the philosophy of the International Commission on Radiological Protection (ICRP), levels should be as low as is reasonably achievable given the economic and social considerations, but should not exceed the MAC.

3.2 Aesthetic characteristics and other considerations

The water quality characteristics discussed in this section do not directly affect the safety of a water supply but may cause aesthetically objectionable effects or render a water unsuitable for domestic use. The primary goal in setting objectives on the basis of aesthetic considerations is to produce a drinking water that is pleasant to consumers. Compliance with these objectives may result in associated health benefits. Pleasing aesthetic qualities will promote consumer confidence in their water works and discourage the use of unregulated water sources.

Aesthetic objectives (AO) have been derived for a number of chemical and physical parameters/characteristics that affect the aesthetic quality of drinking water or interfere with good water quality control practices. The existence of objectives as defined above should not be regarded as implying that the quality of the drinking water may be degraded to the specified levels. In fact, a continuous effort should be made to promote the highest possible quality in drinking water. An aesthetic objective should not be exceeded when more suitable supplies are, or can be made available at a reasonable cost.

3.2.1 Microbiological characteristics

Several species of algae, protozoa and other microorganisms can cause problems such as unpleasant taste and clogged filters. Iron bacteria can cause discolouration, turbidity and taste problems or form slime and iron oxide accumulations in pipes, thus reducing the capacity of the system. Sulphate reducing bacteria can contribute to corrosion of water mains and to taste and odour problems. Macroorganisms such as nematodes, which may not pose a direct health risk, may harbour pathogenic viruses and bacteria and shield them from disinfectants.

Microbiological examination of drinking water is of value in determining the cause of objectionable tastes and odours and clogging of distribution pipes and filters. Since most of these organisms are removed by conventional treatment, these problems are more likely to occur in supplies where filtration is not practised. Nuisance organisms are particularly difficult to control once they become established within the distribution system. Many are resistant to the disinfecting action of chlorine or may be protected by debris and slime. It is difficult, however, to specify any quantitative limit on these organisms because individual species differ widely in their ability to produce undesirable effects. Many of the problems caused by nuisance organisms are covered by the objectives on the physical characteristics of water.

The population of organisms within a water supply system can be controlled by reducing nutrients entering the system, eliminating entry of invertebrates and keeping the distribution system clean. This can be achieved by efficient treatment allowing only low turbidity water to enter the system, covering reservoirs, maintaining a chlorine residual throughout the distribution system, systematically cleaning the distribution system by flushing and, if necessary, foam swabbing, and applying good practices when repairing or replacing old water mains or preparing new water mains for service. The elimination of dead end water mains in the distribution system will reduce sources of infestations.

3.2.2 Chemical characteristics

The chemical parameters discussed may be aesthetically objectionable, interfere with water treatment processes and distribution systems or stain fixtures and plumbing. Colour, taste and odour problems tend to be associated with high levels of organics. Numerous individual organics may be responsible and therefore, it is not usually practical to set objectives for specific parameters.

3.2.3 Physical characteristics

Physical characteristics provide what are probably the oldest methods of judging water quality. The acceptability of drinking water to consumers still depends to a large degree on colour, clarity, taste, odour and temperature. Certain physical characteristics may also interfere with treatment processes resulting in increased operating costs.

An important consideration in assessing physical characteristics is their effect on, or association with, other water quality parameters. Colour, for example, may be related to the presence of iron or manganese. Temperature affects taste and odour perceptions. Corrosion and incrustations which, in turn, affect colour, taste and odour, can be directly related to pH. Controlling the physical characteristics can result in overall improvement to drinking water quality.

4. SAMPLING, ANALYSIS AND CORRECTIVE ACTION

Samples are taken from water works primarily to determine whether or not the water is safe for human consumption. These samples must therefore be representative of the system as a whole. If samples are carelessly collected or taken from locations that are not representative of the whole system, then the purpose of sampling is defeated. Unrepresentative sampling may even be dangerous because it can give rise to unjustified confidence in the quality of water. It may also cause unnecessary cost and concern. The health significance of a parameter the degree to which its concentration varies over time and the population at risk, should be considered in determining the sampling frequency.

It is important to note that a single sample is of limited value. The most a single sample can show is the water quality at the time and place of sampling. Therefore, it is necessary that repeat samplings be performed and complete records be maintained in order to get an adequate picture of the conditions in the water supply system. Samples taken at consumers' taps provide the greatest assurance about delivered water quality. The use of standard sampling and analytical techniques also allows for valid comparison of data collected in different places at various times and identification of trends in water quality. The availability of reliable, up-to-date and comprehensive information on contaminants to which the public may be exposed is essential for establishing new standards/objectives or revising the current ones.

4.1 Rationale for drinking water monitoring and analysis

The basic objective of drinking water monitoring is to ensure that drinking water delivered to the consumer is safe and aesthetically pleasing. Monitoring and analysis is carried out to:

- assess compliance with the Drinking Water Protection Regulation;
- assess compliance with Certificates of Approval and orders and other requirements related to the water works;
- control the treatment process to ensure achievability of the desired water quality and to monitor treatment efficiency by measuring and recording
  - flow rates (e.g. filter rate, backwash rate, chemical feed rate, air flow rate, etc.); and
  - operating parameters (e.g. elapsed time, turbidity, particle count, pH, temperature, conductivity, aluminum residual, chlorine residual, etc.);
- define cause and effect relationships, thereby aiding in the identification of appropriate remedial action;
- determine ongoing trends and identify changes in water quality;
- provide an early warning of the development of detrimental conditions;
- identify treatment needs and modifications in frequency of monitoring as a result of change and/or degradation of the raw water source; and
- secure public confidence and respond to complaints.

Public confidence in drinking water is greatly influenced by the quality of the monitoring program. More confidence will be placed on the monitoring results when:

- adequate samples are taken of raw, treated and distributed water;
- samples are taken at sufficient frequency so that seasonal and/or temporal variations are apparent;
- there are documented and appropriate sampling and analytical protocols;
- there are validation checks throughout the sampling, analytical and data management procedures; and
- results of the analysis are reported in a timely fashion.

There are three basic locations at which water works should be sampled:

- raw water prior to treatment;
- treated water leaving the facility; and
- distributed water delivered to the consumer.

Samples taken at each location serve several functions:

Raw Water (water entering the treatment plant prior to any chemical addition)

Raw water sampling and analysis provides:

- a measure of source water quality which allows assessment and adjustment of treatment processes;
- information on the source of contaminants; and
- long-term trends in source water quality.

Treated Water (water entering the distribution system after the treatment is complete)

When combined with the raw water data the following can be determined:

- treatment ability and efficiency in removing or destroying chemical contaminants and microbiological organisms;
- creation of by-products from the treatment process and unwanted residuals from treatment chemicals; and
- drinking water quality for those parameters that do not change during distribution (e.g., pesticides, PCBs, mercury).

Distributed Water (water supplied to the consumer)

A **free flowing** sample taken at the consumer's tap provides:

- information on the quality of drinking water that is actually consumed;
- information on those parameters that are known to change during distribution (e.g., THMs, chlorine residual and metals such as lead); and
- a measure of the effect of the distribution system on water quality when compared with the treated water.

A **standing** sample taken from the consumer's tap which provides:

- information on the leaching of metals from the distribution system or the consumer's plumbing into the drinking water;
- worst-case conditions for metals (e.g. lead); and
- the effectiveness of corrosion control practices.

A comprehensive monitoring and assessment program would include information on raw, treated and distributed water quality along with the plant processes and chemical dosages. This would allow proper interpretation and validation of the information based on chemical relationships. The source of a contaminant is more readily identified and thereby appropriate remedial action can be recommended.

It should be noted that, depending on the source (ground or surface water), raw water quality and other site specific considerations, the list of parameters, frequency of sampling and number of sampling locations may vary greatly from site to site. The site-specific requirements for monitoring and analysis are reflected in the terms and conditions of the Certificate of Approval for the particular water supply system.

The description of sampling and analytical requirements for microorganisms (section 4.2) and chemical and physical parameters (section 4.3) are presented in Table 5.

It is required that samples be analyzed by methods and laboratories accredited by the Standards Council of Canada or equivalent and the results assembled and made available for public viewing. However, some of the parameters set forth in this document can be analyzed in the field by a Licensed Operator/Water Analyst at a water works. The Ministry of Health and Long Term Care also conducts microbiological analysis in response to public health concerns and is the agency responsible for microbiological analysis of private supplies.

4.2 Microbiological organisms

Contamination of supplies by untreated sewage or poorly managed livestock manure runoff present the greatest risk to public health from microorganisms associated with drinking water. Microbiological testing and monitoring chlorine residuals provide the most appropriate means for the detection and protection against such organisms. Contamination is often intermittent and may not be revealed by the examination of a single sample. Proper supervision of a water works is usually based on results of multiple microbiological samples at multiple locations. Sampling and analysis requirements for microbiological organisms, chlorine residual and other parameters are presented in Table 5.

4.2.1 Frequency and location of sampling and analysis for microbiological organisms

Sampling frequency and location should be sufficient to maintain proper supervision of the water works and ensure safe microbiological quality. Frequency of analyses and location of sampling points shall be established by the water works owner after assessment of the source water, including source protection protocols and methods of treatment. Samples from the distribution system should not be restricted to the same points on each occasion. All samples must be tested for total coliforms as well as *Escherichia coli* and/or fecal coliforms. In addition, a minimum of 25% must be analyzed for heterotrophic plate count or background colonies on a total coliform membrane filter medium.

For water works treating surface or ground water, samples must be taken at least weekly from the raw water source (in a ground water source this means each well) and at the point the treated water enters the distribution system. In addition, the operator **must** ensure that the disinfection process is functioning properly at all times.

In addition to the above, the number of microbiological samples to be collected, and the frequency of sampling, from a distribution system is outlined in Table 5.

4.2.2 Indicators of adverse water quality, notification procedure and corrective actions

Each of the following is an indicator of adverse water quality:

a) *Escherichia coli* (*E. coli*) or fecal coliform is detected in any required sample other than a raw water sample. (Corrective action: Increase the chlorine dose and flush the mains to ensure that a total chlorine residual of at least 1.0 mg/L or a free chlorine residual of 0.2 mg/L is achieved at all points in the affected part(s) of the distribution system. Resample and analyze. Corrective action should begin immediately and continue until *E. coli* and fecal coliforms are no longer detected in two consecutive sets of samples or as instructed by the local Medical Officer of Health.)

b) Total coliforms detected (but not *Escherichia coli* or other fecal coliforms) in any required sample other than a raw water sample. (Corrective action: Resample at the same site and analyze. If confirmed to be positive, increase the chlorine dose and flush the mains to ensure that a total chlorine residual of at least 1.0 mg/L or a free chlorine residual of 0.2 mg/L to all points in the affected part(s) of the distribution system. Corrective action outlined should begin immediately and continue until total coliforms are no longer detected in two consecutive sets of samples or as instructed by the local Medical Officer of Health.)

c) Unchlorinated water is directed to the distribution system, where chlorination is used or required. This includes water in the distribution system which has less than 0.05 mg/L of free chlorine residual when tested. (Corrective action: Restore chlorination immediately and follow instructions as directed by the local Medical Officer of Health.)

d) Samples, other than raw water samples, containing more than 500 colonies per mL on a heterotrophic plate count analysis. (Corrective action: Resample and analyze. On confirmation, call the local Medical Officer of Health again and consult.)

e) Samples, other than raw water samples, containing more than 200 background colonies on a total coliform membrane filter analysis. (Corrective action: Resample and analyze. On confirmation, call the local Medical Officer of Health again and consult.)

f) Aeromonas spp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Clostridium* spp. or fecal streptococci (Group D streptococci) are detected in samples, other than raw water samples. (Corrective action: Resample and analyze. On confirmation, call the local Medical Officer of Health again and consult.)

Pursuant to the Drinking Water Protection Regulation, when a,b,c,d,e, and/or f occurs, the laboratory and the owner of the water works shall immediately notify the MOE Spills Action Centre (SAC) and the local Medical Officer of Health. In the case of c the owner of the water works shall immediately notify the MOE SAC and the local Medical Officer of Health.

4.2.2.1 Resampling

Resampling should consist of a minimum of three samples to be collected for each positive sampling site: one sample should be collected at the affected site; one at an adjacent location on the same distribution line; and a third sample should be collected some distance upstream on a feeder line toward the water source. The chlorine residual and the time of sampling for each site should also be noted at each sampling location. The collection of three samples is considered the minimum number for each positive sampling site. The measurement of the chlorine residual in the vicinity of the positive sampling site may assist in determining the extent of the contamination within the distribution system.

4.3 Chemical and physical parameters

4.3.1 Sampling and analysis

A water supply source may be susceptible to chemical contamination, or may contain naturally occurring chemicals that can result in the treated water exceeding physical or chemical water quality standards/objectives as stipulated in this document. Such contamination could become a health hazard to consumers served by the water works.

Table 5 contains the level of sampling and analysis requirements. Water works owners must also comply with the sampling and reporting requirements in Orders and Certificates of Approval.

In addition to the above, the water works owner must conform with the resampling and notification provisions contained in Section 4.3.2 whenever an analysis of treated water or distribution system water indicates that a MAC or IMAC has been exceeded pursuant to the Drinking Water Protection Regulation.

The Ministry of the Environment will evaluate, during routine inspections, the sampling programs in use at water works against the sampling and analysis requirements as prescribed in the Drinking Water Protection Regulation and/or Certificate of Approval and/or Order.

The analytical results of all sampling are to be maintained by the water works owner at least for a period of time of five years or for a period compatible with the frequency of sampling.

All water works must monitor according to Table 5.

Table 5 - Sampling and Analysis Requirements
Samples shall be taken from the point at which treated water enters the distribution system unless directed otherwise in the following table. "Distribution samples" or samples required to be taken "in the distribution system" shall be taken in the distribution system from a point significantly beyond the point at which treated water enters the distribution system. All sampling shall be done by taking grab samples unless "continuous monitoring" is specified. Continuous monitoring implies that sampling and analysis is done by continuous monitoring equipment that forms part of the water treatment or distribution system. Sampling and analysis is required for all parameters indicated in the first column, unless an entry in one of the other columns indicates otherwise. Ground water under the direct influence of surface water is considered to be surface water.

Table 5 - Sampling and Analysis Requirements			
Microbiological Table A	Up to 100,000 population, a minimum of 8 samples plus an additional 1 sample per 1,000 population, shall be taken monthly in the distribution system, with at least one such sample taken every week. Over 100,000 population, a minimum of 100 samples plus an additional 1 sample per 10,000 population, shall be taken monthly in the distribution system, with at least three such samples taken every week. The above samples need not be analyzed for heterotrophic plate count, provided that at least 25% of each batch of samples sent to a laboratory is analyzed for either heterotrophic plate count or background colonies on a total coliform membrane filter analysis. A sample must be taken at least once per week from the point at which treated water enters the distribution system. A sample must be taken at least once per week from the raw water source (in a ground water source this means each well)		
Parameter	Surface Water Source with Filtration	Surface Water Source Without Filtration	Ground Water Source
Turbidity	grab sample every four hours or continuous monitoring on each filter effluent line for systems serving fewer than 500 persons, monitoring can be reduced to two grab samples per day.	continuous monitoring	grab sample once a day

Table 5 - Sampling and Analysis Requirements			
Chlorine Residual (equivalent to free chlorine residual)	continuous monitoring for systems serving over 3,000 grab samples for systems serving 3,000 or fewer as follows: population frequency ≤ 500 1/day 500-1,000 2/day 1,001-2,500 3/day 2,501-3,000 4/day distribution samples at the same frequency and location as required for microbiological sampling	continuous monitoring for systems serving over 3,000 grab samples for systems serving 3,000 or fewer as follows: population frequency ≤ 500 1/day 500-1,000 2/day 1,001-2,500 3/day 2,501-3,000 4/day distribution samples at the same frequency and location as required for microbiological sampling	one grab sample per day shall be taken distribution samples at the same frequency and location as required for microbiological sampling
Fluoride	continuous monitoring or daily monitoring using grab sampling where treatment process includes fluoridation all other supply systems should monitor for fluoride annually.	continuous monitoring or daily monitoring using grab sampling where treatment process include fluoridation all other supply systems should monitor for fluoride annually.	continuous monitoring or daily monitoring using grab sampling where treatment process include fluoridation all other supply systems should monitor for fluoride annually.
Volatile Organics Table B	trihalomethanes quarterly in the distribution system at a point reflecting the maximum residence time in the distribution system. all others quarterly.	trihalomethanes quarterly in the distribution system at a point reflecting the maximum residence time in the distribution system. all others quarterly.	trihalomethanes quarterly in the distribution system at a point reflecting the maximum residence time in the distribution system. all others quarterly.

Table 5 - Sampling and Analysis Requirements			
Inorganics Table C and Sodium	annually in addition, lead shall be sampled annually in the distribution system at a point reflecting the maximum residence time in the distribution system sampling for sodium is not required	annually in addition, lead shall be sampled annually in the distribution system at a point reflecting the maximum residence time in the distribution system sampling for sodium is not required	every three years in addition, lead shall be sampled annually in the distribution system at a point reflecting the maximum residence time in the distribution system sodium shall be sampled every five years
Nitrates/Nitrites	quarterly	quarterly	quarterly
Pesticides & PCB Table D	quarterly	quarterly	quarterly

4.3.2 Assessment and Corrective Action

If the results of analyses indicate that the level of any parameter exceeds its MAC or IMAC, the local Medical Officer of Health and the MOE SAC must be notified immediately by the water works owner and laboratory and immediate resampling is required.

If a pesticide not listed in Table 1 is detected in any test the local Medical Officer of Health and the Ministry of the Environment Spills Action Centre must be notified. Regardless of the source a corresponding raw water sample must be taken and analyzed. On confirmation, call the local Medical Officer of Health again and consult.

When a volatile organic compound is detected above trace levels, unless known to be a by-product of the treatment process, a corresponding raw water sample must be taken and analyzed. Monitoring should be continued until the problem has been corrected.

4.4 Radiological Parameters

4.4.1 Sampling and Analysis

The frequency of sampling for radionuclides is dependent on the concentration present in the supply. The higher the concentration of a radionuclide the more frequent the sampling. Where water sources are subject to discharges of radioactive waste, the sampling frequency for specific radionuclides should be increased.

Most radionuclides can either be measured directly or expressed in terms of surrogate measurements such as gross alpha emission (e.g., radium-226) and gross beta emission (e.g., strontium-90, iodine-131, cesium-137). The gross alpha and gross beta determinations are only suitable for preliminary screening procedures. Compliance with the standards may be inferred if these are less than the most stringent MACs (see Table 3). When these limits are exceeded, the specific radionuclides must be measured directly. Tritium, a gross beta emitter, must be measured separately because the screening process is not sufficiently sensitive to detect low levels of tritium.

4.4.2 Assessment and Corrective Action

If the results of analyses indicate that the level of any parameter exceeds its MAC, the local Medical Officer of Health and the MOE SAC should be notified immediately by the water works owner and laboratory and immediate resampling is required and monitoring should be continued until the problem has been corrected.

Table A - Microbiological

Total Coliforms
Escherichia coli and/or fecal coliforms
heterotrophic plate counts

Table B **Volatile Organics**

Benzene	Monochlorobenzene
Carbon Tetrachloride	Tetrachloroethylene
1,2-Dichlorobenzene	Toluene
1,4-Dichlorobenzene	Trihalomethanes
1,2-Dichloroethane	Trichloroethylene
1,1-Dichloroethylene	Vinyl chloride
Dichloromethane	Xylene
Ethylbenzene	

Table C **Inorganics**

Arsenic	Lead
Barium	Manganese
Boron	Mercury
Cadmium	Nitrite
Chromium	Nitrate
Copper	Selenium
Iron	Uranium

Table D **Pesticides and PCB**

Alachlor	DDT	Paraquat
Aldicarb	2,4-D	Parathion Pentachlorophenol
Aldrin+Dieldrin	Diclofop-methyl	Phorate
Atrazine	Dimethoate	Picloram
Azinphos-methyl	Dinoseb	PCB
Bendiocarb	Diquat	Prometryne
Bromoxynil	Diuron	Simazine
Carbaryl	Glyphosate	Temephos
Carbofuran	Heptachlor +	Terbufos
Chlordane(Total)	heptachlor epoxide	2,3,4,6-Tetrachlorophenol
Chlorpyrifos	Lindane(Total)	Triallate
Cyanazine	Malathion	2,4,6.-Trichlorophenol
Diazinon	Methoxychlor	Trifluralin
Dicamba	Metolachlor	2,4,5-T
2,4-Dichlorophenol	Metribuzin	

APPENDIX A - Description of Individual Parameters

Alachlor (herbicide)

The interim maximum acceptable concentration (IMAC) for alachlor in drinking water is 0.005 mg/L. This IMAC was developed in February 1985 by Health Canada, at the request of the Ontario government, in response to detection of this herbicide in municipal and private drinking water. Alachlor is a chloroacetanilide herbicide used mainly on corn and soybeans to control the growth of weeds. It is applied to cornfields prior to corn emergence to kill annual grasses. Alachlor is a proven animal carcinogen and a possible human carcinogen. In November of 1985, the use of alachlor was banned in Canada.

Aldicarb (insecticide)

The maximum acceptable concentration for aldicarb in drinking water is 0.009 mg/L. Aldicarb is a carbamate insecticide used in relatively low quantities for the control of specified insects. It was used on potatoes as well as on sugar beets and greenhouse ornamentals for aphid and root maggot control. Since aldicarb is highly soluble in water, persistent and mobile in soils, it has a high potential to enter ground water supplies. Available evidence suggests that aldicarb is not carcinogenic. The use of aldicarb was withdrawn by the manufacturer in the late 1980s.

Aldrin + Dieldrin (insecticide)

The maximum acceptable concentration for aldrin+dieldrin in drinking water is 0.0007 mg/L. Aldrin and dieldrin are organochlorine pesticides used to control soil insects. Aldrin is not often found in aquatic systems because it quickly oxidizes to dieldrin, which is very persistent. Most uses of aldrin and dieldrin were banned in Ontario in 1969 except for termite control under appropriate circumstances. This remaining use was banned in Ontario in April 1994.

Alkalinity (inorganic)

Alkalinity is a measure of the resistance of the water to the effects of acids added to water. The recommended operational range for alkalinity in coagulant-treated drinking water is 30 to 500 mg/L expressed as calcium carbonate. Alkalinity over 30mg/L assists floc formation during the coagulation process. In some circumstances chemicals must be added to boost alkalinity before addition of a coagulant. Water with low alkalinity may tend to accelerate natural corrosion leading to "red water" problems whereas high alkalinity waters may produce scale incrustations on utensils, service pipes and water heaters. Water treatment processes, which do not use a coagulant generally, do not require alkalinity measurement or adjustment.

Aluminum (inorganic)

Aluminum in untreated water is present in the form of very fine particles of alumino-silicate clay. These clay particles are effectively removed in coagulation/filtration. Aluminum found in coagulant treated water is due to the presence of aluminum left over from use of the coagulant. Optimization of treatment should be applied to reduce this "residual" aluminum to under the operational guideline of 0.1 mg/L. High residual aluminum can cause coating of the pipes in the distribution system resulting in increased energy requirements for pumping, interferences with certain industrial processes and flocculation in the distribution system.

Medical studies have not provided clear evidence that residual aluminum has any effect on health.

Arsenic (inorganic)

The interim maximum acceptable concentration for arsenic in drinking water is 0.025 mg/L. Arsenic is a known carcinogen and must therefore be removed by treatment where present at levels over this concentration.

Arsenic is sometimes found at higher levels in ground water in hard rock areas (e.g. Canadian Shield) in Ontario through the natural dissolution of arsenic containing minerals, in some mine drainage waters and in some mine waste leachates. Arsenic is present at very low concentrations in most surface waters.

Atrazine (herbicide)

The interim maximum acceptable concentration for atrazine plus N-dealkylated metabolites in drinking water is 0.005 mg/L. Atrazine, a triazine pesticide, is used mainly as a pre-emergent herbicide on corn for annual grass control. Atrazine is highly persistent and moderately mobile in soil.

Azinphos-methyl (insecticide)

The maximum acceptable concentration for azinphos-methyl in drinking water is 0.02 mg/L. Azinphos-methyl, an organophosphorus insecticide, is a broad spectrum insecticide used against foliage-feeding insects.

Barium (inorganic)

The maximum acceptable concentration for barium in drinking water is 1.0 mg/L. Barium is a common constituent in sedimentary rocks such as limestone and dolomite where it is accompanied by strontium and much larger amounts of calcium. As a result, hard water contains small amounts of barium but seldom at concentrations greater than 1 mg/L. Most treatment methods used for water softening are effective for barium removal.

Bendiocarb (insecticide)

The maximum acceptable concentration for bendiocarb in drinking water is 0.04 mg/L. Bendiocarb is a carbamate insecticide used to control specific insects in buildings and greenhouses.

Benzene (organic)

The maximum acceptable concentration of benzene in drinking water is 0.005 mg/L. Benzene is present in small amounts in gasoline and other refined petroleum products. Long term exposure to high levels of benzene has been shown to increase cancer risk. Benzene is reported to occur in vehicle emissions and cigarette smoke. Drinking water is not considered a significant source of benzene because objectionable taste and odour discourages consumption.

Benzo(a)pyrene (organic)

The maximum acceptable concentration for benzo(a)pyrene in drinking water is 0.00001 mg/L. Benzo(a)pyrene is formed during the incomplete burning of organic matter and is found in poorly adjusted diesel exhaust and in coal/coking tar. Benzo(a)pyrene is classed as a PAH (polycyclic aromatic hydrocarbon) and has strong carcinogenic properties.

Boron (inorganic)

The interim maximum acceptable concentration for boron in drinking water is 5.0 mg/L. Boron in water is most commonly found as borate. Acute boron poisonings have resulted from the use of borates as antiseptic agents and from accidental ingestion, however the consumed amounts were much higher than would be encountered through drinking water. Infants, the elderly and individuals with kidney diseases are most susceptible to the toxic effects of boron compounds.

Bromoxynil (herbicide)

The interim maximum acceptable concentration for bromoxynil in drinking water is 0.005 mg/L. Bromoxynil is a hydroxybenzonitrile herbicide used in Ontario for the control of specific weed seedlings in grain crops.

Cadmium (inorganic)

The maximum acceptable concentration for cadmium in drinking water is 0.005 mg/L. Cadmium is a relatively rare element that is extremely unlikely to be present as a significant natural contaminant in drinking water. Cadmium compounds used in electroplated materials and electroplating wastes may be a significant source of drinking water contamination. Other than occupational exposure and inhalation from cigarette smoke, food is the main source of cadmium intake.

Carbaryl (insecticide)

The maximum acceptable concentration for carbaryl in drinking water is 0.09 mg/L. Carbaryl is a commonly used broad spectrum carbamate insecticide used in agriculture and forestry for control of foliar pests and as a home and garden product for specific garden and lawn pests. It is also used for ectoparasite control on livestock and pets. Available evidence suggests that carbaryl is not carcinogenic.

Carbofuran (insecticide)

The maximum acceptable concentration for carbofuran in drinking water is 0.09 mg/L. Carbofuran, trade-name Furadan, is a broad spectrum carbamate insecticide used in agriculture for control of foliar pests. It may also be used to treat soil at planting time to control root maggot, wireworm and some species of nematodes.

Carbon tetrachloride (organic)

The maximum acceptable concentration for carbon tetrachloride in drinking water is 0.005 mg/L. Carbon tetrachloride is likely to be found only in ground water from old industrial sites where chlorinated solvents were made or used. It is a well-known liver toxin and is classified as probably carcinogenic to humans.

Chloramines (new)

The maximum acceptable concentration for chloramines in drinking water is 3.0 mg/L. Chloramines are produced when ammonia is added to chlorinated water during the disinfection process. Chloramine is a very weak disinfectant that is most suited for use as a stable distribution system disinfectant. Chloramination usually results in the production of lower levels of trihalomethanes and other chlorination by-products in the drinking water.

Chlordane (insecticide)

The maximum acceptable concentration for chordane in drinking water is .007 mg/L. Chlordane is an organochlorine insecticide that was once used extensively in agriculture as a soil insecticide and for domestic control of cockroaches, ants and termites. Chlordane is very persistent in soil. The use of chlordane in Ontario was banned in 1994.

Chloride (inorganic)

Chloride is a common non-toxic material present in small amounts in drinking water and produces a detectable salty taste at the aesthetic objective level of 250 mg/L. Chloride is widely distributed in nature, generally as the sodium ($NaCl$), potassium (KCl) and calcium ($CaCl_2$) salts.

Chlorpyrifos (insecticide)

The maximum acceptable concentration for chlorpyrifos in drinking water is 0.09 mg/L. Chlorpyrifos is a commonly used organophosphorus insecticide used for the control of insects on agricultural crops, for domestic use and for flea and tick control. Available evidence suggests that chlorpyrifos is not carcinogenic.

Chromium (inorganic)

The maximum acceptable concentration for chromium in drinking water is 0.05 mg/L. Trivalent chromium, the most common and naturally occurring state of chromium, is not considered to be toxic. However, if chromium is present in raw water, it may be oxidized to a more harmful hexavalent form during chlorination. Chromium in the more highly oxidised form may be present in older yellow paints and in residues from plating operations and around old recirculating water cooling systems.

Colour (physical)

The aesthetic objective for colour in drinking water is 5 TCU (True Colour Units). Water can have a faint yellow/brown colour which is often caused by organic materials created by the decay of vegetation. Sometimes colour may be contributed to by iron and manganese compounds produced by processes occurring in natural sediments or in aquifers. The presence of organic materials are the main cause of disinfection by-products when water is treated with chlorine.

Copper (inorganic)

The aesthetic objective for copper in drinking water is 1.0 mg/L. Copper occurs naturally in the environment but is rarely present in raw water. Copper is used extensively in domestic plumbing in tubing and fittings and is an essential trace component in food. Drinking water has the potential to be corrosive and to cause copper to dissolve in water. At levels above 1.0 mg/L, copper may impart an objectionable taste to the water. Although the intake of large doses of copper has resulted in adverse health effects such as stomach upsets, the levels at which this occurs are much higher than the aesthetic objective.

Cyanazine (herbicide)

The interim maximum acceptable concentration for cyanazine in drinking water is 0.01 mg/L. Cyanazine is a triazine herbicide registered for control of weeds in crop and non-crop areas.

Cyanide (inorganic)

The maximum acceptable concentration for cyanide in drinking water is 0.2 mg/L. Cyanide is widely used in metals plating and refining industries, and industrial effluents are the major potential sources of cyanide contamination. Cyanide at levels less than 10 mg/L is readily detoxified in the body to thiocyanate. Lethal toxic effects of cyanide usually occur only when this detoxification mechanism is overwhelmed. The maximum acceptable concentration for free cyanide provides a safety factor of approximately 25. Adequate chlorination will oxidize cyanide and reduce it to a level below this limit.

Diazinon (insecticide)

The maximum acceptable concentration for diazinon in drinking water is 0.02 mg/L. Diazinon is an organophosphorus insecticide that is used to control foliar and soil dwelling pests. It is also used for control of flies in barns and for ant and cockroach control.

Dicamba (herbicide)

The maximum acceptable concentration for dicamba in drinking water is 0.12 mg/L. Dicamba is a benzoic acid herbicide that is used for control of broadleaf weeds in grains, corn, flax, sorghum, pastures and weed control in lawns.

1,2-Dichlorobenzene (organic)

The maximum acceptable concentration for 1,2-dichlorobenzene in drinking water is 0.2 mg/L and the aesthetic objective is 0.003 mg/L. Although health effects from 1,2-dichlorobenzene are negligible below 0.2 mg/L, it does impart an unpleasant taste to water if present above 0.003 mg/L. It is used in a variety of specialty chemical blends (degreasing agents, imported dye carriers). There is sufficient evidence to suggest that 1,2-dichlorobenzene is probably non-carcinogenic.

1,4-Dichlorobenzene (organic)

Dichlorobenzene is a persistent synthetic material with a strong "medicinal" smell. It has been used widely in toilet pucks and mothballs. The maximum acceptable concentration for 1,4-dichlorobenzene in drinking water is 0.005 mg/L At levels above the aesthetic objective of 0.001 mg/L, 1,4-dichlorobenzene imparts an unpleasant taste to the water.

DDT (Dichlorodiphenyltrichloroethane) and Metabolites (insecticides)

The maximum acceptable concentration of DDT and its metabolites in drinking water is 0.03 mg/L. Its persistence in the environment and concerns with potential biomagnification resulting in potential widespread damage to the environment resulted in use restrictions in North America by the late 1960's. DDT was banned in Ontario in 1988.

1,2-Dichloroethane (organic)

An interim maximum acceptable concentration for 1,2-dichloroethane in drinking water is 0.005 mg/L. It is principally used as a starting material in the production of vinyl chloride, as a solvent and a fumigant. It is released into the environment via atmospheric emissions and the discharge of industrial waste waters. There is some information which suggests that 1,2-dichloroethane is an animal carcinogen, but inadequate data to determine human carcinogenicity.

1,1-Dichloroethylene (vinylidene chloride) (new) (organic)

The maximum acceptable concentration for 1,1-dichloroethylene (1,1-dichloroethene, vinylidene chloride, 1,1-DCE) in drinking water is 0.014 mg/L. This chemical is not produced in Canada, however, it is imported for use in the food packaging industry and the textile industry for furniture and automotive upholstery, drapery fabric and outdoor furniture.

Dichloromethane (organic)

The maximum acceptable concentration for dichloromethane in drinking water is 0.05 mg/L. Methylene chloride is an alternative name for dichloromethane. It is used extensively as an industrial solvent for paint-stripping and as a degreasing agent. There is sufficient data to show that dichloromethane is an animal carcinogen, but inadequate data to determine human carcinogenicity.

2,4-Dichlorophenol (organic)

Chlorophenols are highly odorous synthetic materials which are most often present in drinking water due to the action of chlorine on phenolic precursors. Lighter phenols are found in water only as a result of industrial contamination. The maximum acceptable concentration for 2,4-dichlorophenol in drinking water is 0.9 mg/L and the aesthetic objective is 0.0003 mg/L. At levels above 0.0003 ug/L, 2,4-dichlorophenol will impart an unpleasant taste to the water.

2,4-D (2,4-Dichlorophenoxy acetic acid) (herbicide)

The interim maximum acceptable concentration for 2,4-D in drinking water is 0.1 mg/L. 2,4-D is a commonly used chlorophenoxy herbicide used for control of broadleaf weeds in cereal crops and lawns.

Diclofop-methyl (herbicide)

The maximum acceptable concentration for diclofop-methyl in drinking water is 0.009 mg/L. Diclofop-methyl is a chlorophenoxy derivative that is used for control of annual grasses in grain and vegetable crops. It is relatively soluble in water.

Dieldrin + Aldrin (insecticide)

see Aldrin + Dieldrin

Dimethoate (insecticide)

The interim maximum acceptable concentration for dimethoate in drinking water is 0.02 mg/L. Dimethoate is an organophosphorus miticide and insecticide used on a wide range of plants for control of mites and both sucking and leaf-feeding insects. It is also used for fly control in livestock pens. Concentrated preparations can be painted on the trunk and main limbs of large trees to control leaf miner.

Dinoseb (herbicide)

The maximum acceptable concentration for dinoseb in drinking water is 0.01 mg/L. Dinoseb is a contact herbicide and desiccant. Dinoseb is no longer used in Ontario.

Dioxins (organic)

The interim maximum acceptable concentration for dioxin, the commonly used name for any chlorinated dibenzodioxin or dibenzofuran, in drinking water is 15 pg/L (expressed as 2,3,7,8,TCDD toxicity equivalents (TEQ)/L). Dioxins are formed in very small amounts in combustion processes, particularly combustion of chlorine containing materials such as scrap tires and, potentially, in some poorly controlled industrial processes such as bleached paper manufacturing.

Diquat (herbicide)

The maximum acceptable concentration for diquat in drinking water is 0.07 mg/L. Diquat is a bipyridilium herbicide used primarily as a crop desiccant in seed crops and as an aquatic herbicide.

Dissolved Organic Carbon (DOC) (Organic)

The aesthetic objective for dissolved organic carbon (DOC) in drinking water is 5 mg/L. High DOC is an indicator of possible water quality deterioration during storage and distribution due to the carbon being a growth nutrient for biofilm dwelling bacteria. High DOC is also an indicator of potential chlorination by-product problems. Coagulant treatment or high pressure membrane treatment can be used to reduce DOC.

Diuron (herbicide)

The maximum acceptable concentration for diuron in drinking water is 0.15 mg/L. Diuron is a substituted urea-based herbicide used for the control of vegetation in crop and non-crop areas, including industrial sites and rights-of-way. It is moderately soluble in water.

Escherichia coli (microbiological)

Escherichia coli should not be detected present in any drinking water sample. *Escherichia coli* is a fecal coliform and can be detected using membrane filtration or presence/absence methods. Since *Escherichia coli* is present in fecal matter and prevalent in sewage, but is rapidly destroyed by chlorine, it is a strong indicator of recent fecal pollution. Contamination with sewage as shown by positive e-coli tests would strongly suggest presence of pathogenic bacteria and viruses, as well as more chlorine resistant pathogens such as giardia and cryptosporidium which are much more difficult to detect.

Ethylbenzene (organic)

The taste/odour related aesthetic objective for ethylbenzene in drinking water is 0.0024 mg/L. Ethylbenzene is a component of the BTEX gasoline additive used for octane rating boosting. It is also used in solvent based paint formulations.

Fecal coliform (microbiological)

Fecal coliforms should not be detected in any treated drinking water sample. The fecal coliform group are a portion of the coliform group that is capable of fermenting lactose at 44 to 45 ^{0}C within 48 hours. *Escherichia coli* is the fecal coliform most frequently associated with recent fecal pollution. The presence of fecal coliforms in drinking water is an indication of sewage contamination.

Fluoride (inorganic)

Where fluoride is added to drinking water, it is recommended that the concentration be adjusted to 1.0(+/-0.2), the optimum level for control of tooth decay. Where supplies contain naturally occurring fluoride at levels higher than 1.5 mg/Lmg/L but less than 2.4 mg/L the Ministry of Health and Long-Term Care recommends an approach through local boards of health to raise public and professional awareness to control excessive exposure to fluoride from other sources. Levels above the MAC must be reported to the local Medical Officer of Health.

Glyphosate (herbicide)

The interim maximum acceptable concentration for glyphosate in drinking water is 0.28 mg/L. Glyphosate is a broad-spectrum, non-selective herbicide used for weed control on rights-of-way, forestry plantations and in-site preparations for planting of crops, as well as for domestic control of plants. It is very soluble in water.

Hardness (inorganic)

The operational guideline for hardness in drinking water is set at between 80 and 100 mg/L as calcium carbonate This value is set to aid in water source selection where a choice exists. Hardness is caused by dissolved calcium and magnesium, and is expressed as the equivalent quantity of calcium carbonate. On heating, hard water has a tendency to form scale deposits and can form excessive scum with regular soaps. However, certain detergents are largely unaffected by hardness. Conversely, soft water may result in accelerated corrosion of water pipes. Hardness levels between 80 and 100 mg/L as calcium carbonate ($CaCO_3$) are considered to provide an acceptable balance between corrosion and incrustation. Water supplies with a hardness greater than 200 mg/L are considered poor but tolerable. Hardness in excess of 500 mg/L in drinking water is unacceptable for most domestic purposes (see the entry below for sodium).

Heptachlor + Heptachlor epoxide (insecticide)

The maximum acceptable concentration of heptachlor + heptachlor epoxide in drinking water is 0.003 mg/L. Heptachlor is an organochlorine insecticide once used in agriculture for control of soil insects. Heptachlor use has been banned in Canada since 1969.

Heterotrophic Plate Count (microbiological)

The HPC (heterotrophic plate count) is a method of measuring the aerobic bacterial content in water. Samples are incubated for 48 hours on a selected nutrient at 35° Celsius. Levels of bacteria detected by this test should not exceed 500 colonies per mL of sample. HPC testing can be used to monitor disinfection efficiency at water treatment plants and to measure water quality deterioration in distribution systems and in reservoirs. (Standard plate count is an older name for HPC testing.)

Iron (inorganic)

Iron may be present in ground water as a result of mineral deposits and chemically reducing underground conditions. It may also be present in surface waters as a result of anaerobic decay in sediments and complex formation. The aesthetic objective for iron, set by appearance effects, in drinking water is 0.3 mg/L. Excessive levels of iron in drinking water supplies may impart a brownish colour to laundered goods, plumbing fixtures and the water itself; it may produce a bitter, astringent taste in water and beverages; and the precipitation of iron can also promote the growth of iron bacteria in water mains and service pipes. Iron based coagulants such as ferric sulfate can be highly effective in treatment processes at removing particles from water and leave very little residual iron in the treated water.

Lead (inorganic)

The maximum acceptable concentration for lead in drinking water is 0.01 mg/L. This applies to water at the point of consumption since lead is only present as a result of corrosion of lead solder, lead containing brass fittings or lead pipes which are found close to or in domestic plumbing and the service connection to buildings. Lead ingestion should be avoided particularly by pregnant women and young children ,who are most susceptible.

It is recommended that only the cold water supply be used for drinking/consumption and only after five minutes of flushing to rid the system of standing water. Corrosion inhibitor addition or other water chemistry adjustments may be made at the treatment plant to reduce lead corrosion rates where necessary.

Lindane (insecticide)

The maximum acceptable concentration for lindane in drinking water is 0.004 mg/L. Lindane is an organochlorine insecticide used for seed treatment and may also be used in pharmaceutical preparations of human lice and mite shampoos. The chemical name for lindane is gamma-BHC (an isomer of hexachlorocyclohexane).

Malathion (insecticide)

The maximum acceptable concentration for malathion in drinking water is 0.19 mg/L. Malathion is a wide spectrum organophosphorus insecticide used on fruits and vegetables, as well as for mosquito, fly, flea and tick control. It has low mammalian toxicity.

Manganese (inorganic)

The colour related aesthetic objective for manganese in drinking water is 0.05 mg/L. Like iron, manganese is objectionable in water supplies because it stains laundry and fixtures black, and at excessive concentrations causes undesirable tastes in beverages. Manganese is present in some ground waters because of chemically reducing underground conditions coupled with presence of manganese mineral deposits. Manganese is also occasionally present, seasonally, in surface waters when anaerobic decay processes in sediments is occurring.

Mercury (inorganic)

The maximum acceptable concentration for mercury in drinking water is 0.001 mg/L. Possible sources of mercury in drinking water include air pollution from coal combustion, waste incineration and from metal refining operations and from natural mineral deposits in some hard rock areas. Food is the major source of human exposure to mercury, with freshwater fish being the most significant local source.

Methane (organic)

The aesthetic objective due to gas bubble release and violent spurting from taps for methane is 3 L/m^3. Methane may be a problem in ground water since it can cause mechanical damage by causing water hammer. Methane occurs naturally in some ground water and acts as a stimulant for microbiological fouling in the distribution system. Methane is not detected in dissolved organic carbon (DOC) analysis and its carbonaceous content is, therefore, additional to any DOC result. If methane is allowed to accumulate in confined areas, the potential for explosive combustion exists.

Methoxychlor (insecticide)

The maximum acceptable concentration for methoxychlor in drinking water is 0.9 mg/L. Methoxychlor is an organochlorine insecticide. It is non-persistent and non-accumulative in biological tissues, making it an attractive insecticide for use on products nearing harvest, in dairy barns for housefly control and as either a larvicide or adulticide against black flies and mosquitoes.

Metolachlor (herbicide)

The interim maximum acceptable concentration for metolachlor in drinking water is 0.05 mg/L. Metolachlor is a selective herbicide used for pre-emergence and pre-plant broad leaf weed control in corn, soybeans, peanuts, grain sorghum, pod crops, woody ornamentals and sunflowers.

Metribuzin (herbicide)

The maximum acceptable concentration for metribuzin in drinking water is 0.08 mg/L. Metribuzin is a triazine herbicide used for control of broad leaf weeds and grasses infesting agricultural crops. It is used selectively on soybeans, tomatoes and potatoes, all crops that are highly sensitive to most other triazine herbicides.

Monochlorobenzene or Chlorobenzene (organic)

The maximum acceptable concentration for chlorobenzene in drinking water is 0.08 mg/L and the taste related aesthetic objective is 0.03 mg/L. Chlorobenzene is used in the production of chloronitrobenzene and diphenyl ether, as a rubber intermediate, and as a solvent in adhesives, paints, waxes, polishes and inert solvents. It is also used in metal cleaning operations and may be present in industrial discharges.

Nitrate (inorganic)

The maximum acceptable concentration of nitrates in drinking water is 10 mg/L as nitrogen. Nitrates are present in water (particularly ground water) as a result of decay of plant or animal material, the use of agricultural fertilizers, domestic sewage or treated wastewater contamination, or geological formations containing soluble nitrogen compounds. There is a risk that babies and small children may suffer blood related problems (methaemoglobinaemia) with excess nitrate intake. The nitrate ion is not directly responsible for this condition , but must first be reduced to the nitrite ion by intestinal bacteria. The nitrite reacts with the iron of haemoglobin in red blood cells which are then prevented from carrying oxygen to the body tissues.

Nitrate poisoning, in terms of methaemoglobinaemia, from drinking water appears to be restricted to susceptible infants. Older children and adults drinking the same water are unaffected. Most water-related cases of methaemoglobinaemia have been associated with the use of water containing more than 10 mg/L nitrate as nitrogen. In Canada, no cases of the condition have been reported where the nitrate concentration was consistently less than the maximum acceptable concentration. Where both nitrate and nitrite are present, the total nitrate plus nitrite-nitrogen concentration should not exceed 10 mg/L. In areas where the nitrate content of water is known to exceed the maximum acceptable concentration the public should be informed by the appropriate health authority of the potential dangers of using the water for infants.

Nitrite (inorganic)

The maximum acceptable concentration of nitrite in drinking water, 1.0 mg/L as nitrogen, is based, as with nitrate, primarily on the relationship between nitrite in water and the incidence of infantile methaemoglobinaemia. Nitrite is fairly rapidly oxidized to nitrate and is therefore seldom present in surface waters in significant concentrations. Nitrite may occur in ground water sources, however, if chlorination is practised the nitrite will usually be oxidized to nitrate.

NTA (Nitrilotriacetic Acid) (organic)

The maximum acceptable concentration for NTA in drinking water is 0.40 mg/L. NTA is mainly used in laundry detergents, most of which is eventually disposed of in domestic wastewater. In general, the toxicity of NTA is very low, however, an increased incidence of urinary tract tumours was found in rats and mice that had been fed very large doses of NTA. Risk assessment, together with the relatively poor absorption of ingested NTA by humans, suggests that the risk associated with a NTA level in drinking water of below 0.40 mg/L is negligible.

NDMA (N-Nitrosodimethylamine) (organic)

The interim maximum acceptable concentration for NDMA is 0.000,009 mg/L. NDMA is rarely used industrially but has been used as an antioxidant, as an additive for lubricants, and as a softener of copolymers. It has been detected in some foods particularly smoked foods and very occasionally in treated river/lake water in heavily farmed locations. NDMA is an animal carcinogen.

Odour (physical/chemical)

The contamination of drinking water with offensively odorous substances may have an easily identified cause such as paint solvent odour or odour from diesel fuel or gasoline. In these cases, systems must be flushed to clear the contaminants and contaminating surfaces stripped and repainted. Another common source of musty odours is from harmless, but very smelly substances produced by certain algae. These materials from algae are present in some surface waters from late summer into fall and can sometimes be partly removed using activated carbon treatment. Another common source of odours is sulfide (see below) which is found in some ground waters but not in surface waters. Numerous other substances could cause odour and these are sometimes very hard to identify and correct. The odour of drinking water should be inoffensive.

Organic Nitrogen (organic)

The operational guideline for organic nitrogen in drinking water is 0.15 mg/L. Organic nitrogen is calculated by the difference between the total Kjeldahl nitrogen and the ammonia nitrogen. High levels may be caused by septic tank or sewage effluent contamination. This form of contamination is often associated with some types of chlorine- worsened taste problems. Organic nitrogen at levels above 0.15 mg/L would be typically associated with DOC contribution of 0.6 mg/L. Organic nitrogen compounds frequently contain amine groups which can react with chlorine and severely reduce its disinfectant power. Certain chlorinated organic nitrogen compounds may be responsible for flavour problems that are associated with chlorophenol. Taste and odour problems are common with organic nitrogen levels greater than 0.15 mg/L.

Paraquat (herbicide)

The interim maximum acceptable concentration for paraquat in drinking water is 0.01 mg/L. Paraquat is a highly toxic, bipyridil herbicide used as a contact herbicide and for desiccation of seed crops. It is also used for non-crop and industrial weed control. It is a pre-emergent herbicide used in "no-till" situations or

before planting or crop emergence. It is also registered for aquatic use to control cattails, bulrushes and grasses.

Parathion (insecticide)

The maximum acceptable concentration for parathion in drinking water is 0.05 mg/L. Parathion is an extremely toxic, organophosphorous broad spectrum insecticide used in agriculture against foliar pests and the adult stage of root maggots. In some instances, resistance to parathion has developed and parathion is no longer effective.

Pentachlorophenol (organic)

The maximum acceptable concentration for pentachlorophenol in drinking water is 0.06 mg/L and the taste/odour based aesthetic objective is 0.03 mg/L. Pentachlorophenol is rarely found in commercial use today but was used extensively as a pesticide and wood preservative. It is the most environmentally persistent of the chlorophenols.

Pesticides

Pesticides can be grouped by chemical composition. Pesticides which contain chlorine tend to persist in the environment and may become concentrated in food chains causing health effects in animals such as predators at the top of the chains. Some chlorophenoxy herbicides and cholinesterase-inhibiting compounds, including organo-phosphorus chemicals and carbamates, have a high acute toxicity to mammals. Many of these, however, hydrolyse rapidly in water to form harmless or less harmful products.

Additional information on pesticides can be found on the World Wide Web at:

The EXtension TOXicology NETwork	(http://ace.orst.edu/info/extoxnet/)
Pest Management Regulatory Agency	(http://www.hc-sc.gc.ca/pmra-arla/)
Ontario Pesticides Advisory Committee	(http://www.opac.gov.on.ca/)

pH (physical-chemical)

pH is a parameter that indicates the acidity of a water sample The operational guideline recommended in drinking water is to maintain a pH between 6.5 and 8.5. The principal objective in controlling pH is to produce a water that is neither corrosive nor produces incrustation. At pH levels above 8.5, mineral incrustations and bitter tastes can occur. Corrosion is commonly associated with pH levels below 6.5 and elevated levels of certain undesirable chemical parameters may result from corrosion of specific types of pipe. With pH levels above 8.5, there is also a progressive decrease in the efficiency of chlorine disinfection and alum coagulation.

Phorate (insecticide)

The interim maximum acceptable concentration for phorate in drinking water is 0.002 mg/L. Phorate is an organophosphorus insecticide used for control of sucking insects, larvae of the corn rootworm and leaf-eating beetles.

Picloram (herbicide)

The interim maximum acceptable concentration for picloram in drinking water is 0.19 mg/L. Picloram is a phenoxy alkanoic acid herbicide used for broadleaf weed and brush control on right-of-ways and roadsides. Picloram can be persistent in soil for up to a year after application.

PCBs (Polychlorinated Biphenyls) (organic)

The interim maximum acceptable concentration for PCBs in drinking water is 0.003 mg/L. PCBs are among the most ubiquitous and persistent pollutants in the global ecosystem. In the past, PCBs have been marketed extensively for a wide variety of purposes but are no longer manufactured or used. The available information suggests that drinking water containing PCB, at a concentration of 0.003 mg/L or less, does not pose a health risk.

Prometryne (herbicide)

The interim maximum acceptable concentration for prometryne in drinking water is 0.001 mg/L. Prometryne is a methylthiotriazine herbicide which is used to selectively control annual grasses and broadleaf weeds in crops and non-crops. It can be applied both as a pre-emergent and post-emergent herbicide.

Radionuclides (radiological) (new and revised)

There are 78 new and revised standards (see Table 3) for both natural and artificial radionuclides. They are derived from a 50-year committed effective dose of 0.1 millisievert (mSv) from one year's consumption of water and are expressed in activity concentration units of becquerels per litre (Bq/L). The derivation of radiological guidelines conforms to international radiation protection methodologies. The approach accounts for the total lifetime exposure that will result from any radionuclide ingested in one year, based on its retention in human tissue. The limits are designed to protect human health from the carcinogenic effects of exposure to radionuclides via drinking water.

Selenium (inorganic)

The maximum acceptable concentration for selenium in drinking water is 0.01 mg/L. Selenium occurs naturally in waters at trace levels as a result of geochemical processes such as weathering of rocks. It is difficult to establish levels of selenium that can be considered toxic because of the complex inter-relationships between selenium and dietary constituents such as protein, vitamin E and other trace elements. Food is the main source of selenium intake other than occupational exposure. Selenium is an essential trace element in the human diet. Drinking water containing selenium at the maximum acceptable

concentration of 0.01 mg/L would be the source of only 10 per cent of total selenium intake. The maximum acceptable concentration, therefore, is considered to provide a satisfactory factor of safety against known adverse effects.

Simazine (herbicide)

The interim maximum acceptable concentration for simazine in drinking water is 0.01 mg/L. Simazine is a triazine herbicide which is used for pre-emergence weed control in annual row crops. Simazine is the least soluble of all the triazine herbicides and is easily leached to ground water where it may persist for years.

Sodium (inorganic)

The aesthetic objective for sodium in drinking water is 200 mg/L at which it can be detected by a salty taste. Sodium is not toxic. Consumption of sodium in excess of 10 grams per day by normal adults does not result in any apparent adverse health effects. In addition, the average intake of sodium from water is only a small fraction of that consumed in a normal diet. A maximum acceptable concentration for sodium in drinking water has, therefore, not been specified. Persons suffering from hypertension or congestive heart disease may require a sodium-restricted diet, in which case, the intake of sodium from drinking water could become significant. It is therefore recommended that the measurement of sodium levels be included in routine monitoring programs of water supplies. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L, so that this information may be passed on to local physicians.

Softening using a domestic water softener increases the sodium level in drinking water and may contribute a significant percentage to the daily sodium intake for a consumer on a sodium restricted diet. It is recommended that a separate unsoftened supply be retained for cooking and drinking purposes.

Sulfate (inorganic)

The aesthetic objective for sulfate in drinking water is 500 mg/L. At levels above this concentration, sulfate can have a laxative effect, however, regular users adapt to high levels of sulfate in drinking water and problems are usually only experienced by visitors and new consumers. The presence of sulfate in drinking water above 150 mg/L may result in noticeable taste. The taste threshold concentration, however, depends on the associated metals present in the water. High levels of sulfate may be associated with calcium, which is a major component of scale in boilers and heat exchangers. In addition, sulfate can be converted into sulfide by some anaerobic bacteria creating odour problems and potentially greatly accelerating corrosion.

Sulfide (inorganic)

The odour related aesthetic objective for sulfide in drinking water is 0.05 mg/L as H_2S(hydrogen sulphide). Although ingestion of large quantities of hydrogen sulfide gas can produce toxic effects on humans, it is unlikely that an individual would consume a harmful dose in drinking water because of the associated unpleasant taste and odour. Sulfide is also undesirable in water supplies because, in

association with iron, it produces black stains on laundered items and black deposits on pipes and fixtures. Lower levels of sulfide can be removed effectively from most well water by aeration. Sulfide is oxidized to sulfate in well-aerated waters over a period of hours and consequently sulfide levels in surface supplies are usually very low.

Taste

Taste and odour are intimately interrelated, and consumers frequently mistake odours for tastes. In general, the sense of taste is most useful in detecting the ionic inorganic constituents of drinking water, whereas the sense of smell is most useful in detecting volatile organic constituents. Taste and odour problems constitute the largest category of consumer complaints. Changes in the taste of drinking water may indicate possible contamination of the raw water supply, treatment inadequacies, excessive biological activity due to sediment accumulation, encrustations and/or loss of chlorine residual in the distribution system. A numerical limit for taste has not been specified because there is no accepted method for the quantitative measurement of taste and there is considerable variation among consumers as to which tastes are acceptable. Water provided for public consumption should have an inoffensive taste.

Temephos (insecticide)

The interim maximum acceptable concentration of Temephos in drinking water is 0.28 mg/L. Temephos is an organophosphorus insecticide used to control mosquito and blackfly larvae. It is only slightly soluble in water.

Temperature (physical)

An aesthetic objective is set for maximum water temperature to aid in selection of the best water source or the best placement for a water intake. It is desirable that the temperature of drinking water should not exceed 15° C because the palatability of water is enhanced by its coolness. Low water temperatures offer a number of other benefits. A temperature below 15°C will tend to reduce the growth of nuisance organisms and hence minimize associated taste, colour, odour and corrosion problems. In summer and fall, water temperatures may increase in the distributed water due to the warming of the soil and/or as a result of higher temperatures in the source water. Low temperature facilitates maintenance of a free chlorine residual by reducing the rates of decay of the chlorine. Low water temperature is not necessary to produce water of an acceptable quality.

Terbufos (insecticide)

The interim maximum acceptable concentration of terbufos in drinking water is 0.001 mg/L. Terbufos is an organophosphorus insecticide used for insect control in corn.

Tetrachloroethylene (perchloroethylene) (new)

The recommended maximum acceptable concentration for tetrachloroethylene in drinking water is 0.03 mg/L. Tetrachloroethylene is no longer produced in Canada but continues to be imported primarily as a

solvent for the dry cleaning and metal cleaning industries. It has been found in ground water, primarily after improper disposal or dumping of cleaning solvents.

2,3,4,6-Tetrachlorophenol (organic)

The maximum acceptable concentration of 2,3,4,6-tetrachlorophenol in drinking water is 0.1 mg/L and the aesthetic objective is 0.001 mg/L. At levels above the aesthetic objective, it will impart an unpleasant taste to the water. 2,3,4,6-tetrachlorophenol was used extensively, along with pentachlorophenol, to preserve wood.

Toluene (organic)

The taste/odour related aesthetic objective for toluene in drinking water is 0.024 mg/L. Toluene is used in gasoline and other petroleum products and in the manufacture of benzene derived medicines, dyes, paints, coating gums, resins and rubber. It may be found in industrial effluents.

Total Coliform (microbiological)

The coliform group of bacteria has been the most commonly used indicator of water quality. The coliform group consists of all aerobic and facultatively anaerobic, gram-negative, oxidase-negative, non-spore forming, rod-shaped bacteria that ferment lactose in a broth medium with gas formation within 48 hours at 35°C. Most coliforms also produce the enzyme â-D galactosidase which can be detected with a colour forming reagent. The group generally comprises the genera *Escherichia, Klebsiella, Enterobacter* and *Citrobacter*. The presence of these bacteria in drinking water shows inadequate filtration/disinfection or in the distribution system a continuing loss of the chlorine residual.

MPN, MF and P/A are methods that may be used to detect and measure coliform populations in drinking water. The tests have slightly different sensitivities to the various bacteria. Occasionally samples will produce positive results in one test and not with the others. In all cases where discrepancies are found, results from the method producing the positive result will be used in assessing the water quality.

Total Dissolved Solids (inorganic)

The aesthetic objective for total dissolved solids in drinking water is 500 mg/L. The term "total dissolved solids" (TDS) refers mainly to the inorganic substances dissolved in water. The principal constituents of TDS are chloride, sulphates, calcium, magnesium and bicarbonates. The effects of TDS on drinking water quality depend on the levels of the individual components. Excessive hardness, taste, mineral deposition, or corrosion are common properties of highly mineralized water. The palatability of drinking water with a TDS level less than 500 mg/L is generally considered to be good.

Triallate (herbicide)

The maximum acceptable concentration for triallate in drinking water is 0.23 mg/L. Triallate is a thiocarbamate herbicide used for control of wild oats in grain crops, mustard and sugar beets.

Trichloroethylene (organic)

The maximum acceptable concentration for trichloroethylene in drinking water is 0.05 mg/L. Most trichloroethylene use is in dry cleaning. Some is used in metal degreasing operations and in tetrachloroethylene production. Trichloroethylene may be introduced into surface and ground water through industrial spills and illegal disposal of effluents.

2,4,6-Trichlorophenol (organic)

The maximum acceptable concentration of 2,4,6-trichlorophenol in drinking water is 0.005 mg/L and the taste related aesthetic objective is 0.002 mg/L. It is used in the manufacture of pesticides. The data is sufficient to classify 2,4,6-trichlorophenol as an animal carcinogen but inadequate for human carcinogenicity. The maximum acceptable concentration has been set taking into account additional safety factors.

2,4,5-T (2,4,5-Trichlorophenoxy acetic acid) (herbicide)

The maximum acceptable concentration for 2,4,5-T in drinking water is 0.28 mg/L and the aesthetic objective is 0.02 mg/L. 2,4,5-T is a phenoxy alkanoic acid herbicide that was once an important stem/foliage treatment for deciduous brush control on road sides and power lines. 2,4,5-T is no longer used in Ontario.

Trifluralin (herbicide)

The interim maximum acceptable concentration for trifluralin in drinking water is 0.045 mg/L. Trifluralin is a dinitroaniline herbicide used for weed control in summer fallow and for controlling annual grasses in wheat, barley and canola. Trifluralin is very insoluble in water.

Trihalomethanes (organic) (revised)

The maximum acceptable concentration (MAC) for trihalomethanes (THMs) in drinking water is 0.10 mg/L based on a four quarter moving annual average of test results Trihalomethanes are the most widely occurring synthetic organics found in chlorinated drinking water. The four most commonly detected trihalomethanes in drinking water are chloroform, bromodichloromethane, chlorodibromomethane and bromoform. The principal source of trihalomethanes in drinking water is the action of chlorine with naturally occurring organics (precursors) left in the water after filtration .

Turbidity (physical)

The maximum acceptable concentration for turbidity in drinking water is 1.0 Nephelometric Turbidity Unit (NTU) for water entering the distribution system but much lower turbidity around or less than 0.1 are commonly continuously attained in well operated treatment plants. Turbidity measurements are made frequently to confirm the existence of good operating conditions at all surface water treatment plants and at some ground water plants.

An appearance related aesthetic objective of 5 NTU has been set for water taken at consumers' taps . Turbidity higher than 5 NTU taken at consumer taps generally indicates severe local corrosion and/or poor bacteriological control due to loss of chlorine residual.

Turbidity in water is caused by the presence of suspended tiny particles that scatter light and make the water appear cloudy. These particles are made from matter such as clay, silt, spores, plankton and other microorganisms. The most important health related effect of turbidity is interference with disinfection and with the maintenance of a chlorine residual. Viable coliform bacteria have been detected in waters with turbidity higher than 3.8 NTU even in the presence of free chlorine residuals of up to 0.5 mg/L and after a contact time in excess of 30 minutes. Outbreaks of disease traced to chlorinated water supplies have been associated with high turbidity.

Uranium (inorganic)

The maximum acceptable concentration of uranium in drinking water is 0.1 mg/L. Uranium is normally present in biological systems and aqueous media as the uranyl ion (UO_2^{2+}). Ingestion of large quantities of uranyl ion may result in damage to the kidneys. The uranyl ion may also be responsible for objectionable taste and colour in water, at much higher levels than the concentrations which may cause kidney damage.

Vinyl Chloride (chloroethene) (organic)

The maximum acceptable concentration of vinyl chloride in drinking water is 0.002 mg/L. Vinyl chloride is a synthetic chemical with no known natural sources. It is classified as a human carcinogen. It is used in making PVC (polyvinyl chloride) plastic items such as water main pipe, siding and many other common plastic items all of which are now made in such a way that there is no trace of vinyl chloride present in them.

Xylenes (organic)

There are three isomers of dimethyl benzene, which are almost identical chemically and are collectively called xylenes. The odour related aesthetic objective for total xylenes in drinking water is 0.3 mg/L. Xylenes are used as industrial solvents and as an intermediate for dyes and organic synthesis. They are a component of household paints and paint cleaners and gasoline and other petroleum products.

Zinc (inorganic)

The taste related aesthetic objective for zinc in drinking water is 5.0 mg/L. The concentration of zinc may be considerably higher at the consumer's tap in standing water because of corrosion taking place in galvanized pipes, but this can be cleared easily by brief flushing. Corrosion control using small concentrations of zinc based inhibitors has been found effective in some water systems.

APPENDIX B - Summary of Water Disinfection

Disinfection is the one step in water treatment specifically designed to destroy or inactivate pathogenic organisms and thereby prevent waterborne diseases. The disinfection agents commonly used in water treatment today are chlorine, chloramines, chlorine dioxide, ozone and ultra violet irradiation.

Chlorine

Chlorine was introduced as a disinfectant in water treatment in the early 1900's and has become the predominant method for water disinfection. Apart from its effectiveness as a germicide, chlorine offers other benefits such as colour reduction, taste and odour control, suppression of algal growth and precipitation of iron and manganese. In addition, it is easy to apply, measure, and control, provides a long-lasting residual and is relatively inexpensive. Chlorine, however, can react with naturally occurring organic matter to produce disinfection by-products such as trihalomethanes which need to be monitored.

The disinfecting efficiency of chlorine can be diminished by inadequate contact time, low temperature, high pH, turbidity, ammonia and organic nitrogen, as well as by high levels of iron, manganese and hydrogen sulphide. These parameters should, therefore, be determined to evaluate their effect on chlorine disinfection.

Maintenance of a free chlorine residual

Maintenance of a free chlorine residual throughout a distribution system will protect the quality of the water throughout the system and provide a means of measuring the sanitary integrity of the distribution system. The disappearance of the chlorine residual, where one was formerly carried, provides an immediate indication of the entry of oxidizable matter into the system or of a malfunction in the treatment process. Since the chlorine residual test is quick and easy to perform, immediate corrective action can be taken. With conventional bacteriological testing, results are not available for at least 24 hours during which time the community may be at risk. Requirements for the application of chlorine for disinfection of drinking water in Ontario are outlined in Procedure B13-3 "Chlorination of Potable Water Supplies in Ontario."

Chloramines (combined chlorine)

Chloramines are produced by the reaction of aqueous chlorine and ammonia. Chloramines have less disinfecting power than ozone, free chlorine or chlorine dioxide for identical contact times, but they can be used when it is necessary to maintain a residual for long periods of time (e.g. distribution systems). Chloramines assist in the control of certain taste and odour problems caused by chlorination and keep THM formation to a minimum. Chloramine is a very weak disinfectant most suited for use as a stable distribution system disinfectant. It is recommended that it be used in conjunction with a stronger primary disinfectant.

Chlorine Dioxide

Chlorine dioxide offers a number of advantages over chlorine. Its germicidal potency is not affected by ammonia and pH within the usual range in drinking water; it effectively controls phenolic tastes and

odours: and it is not known to form trihalomethanes. A potential problem with the use of chlorine dioxide may be the formation of chlorite ion which is reported to have detrimental, but poorly defined, health effects. Chlorine dioxide must be produced on-site. Recent advances in on-site generation technology are making chlorine dioxide more attractive for use as a disinfectant.

Ozone

In some respects, ozone is a superior disinfectant to chlorine. It is unaffected by the pH or ammonia content of the water and it is more effective than chlorine against viruses, cysts, fungi and spores. Ozone, however, is unstable and as a result ozone residuals cannot be maintained for long periods of time. Another disinfectant must, therefore, be added after disinfection with ozone that can provide a residual which can be maintained throughout the distribution system. Ozone must be produced on-site. Ozone does not produce chlorinated by-products (such as trihalomethanes) but it may cause an increase in such by-product formation when fed upstream of free chlorine. Ozone may also produce its own oxygenated by-products such as aldehydes, ketones, carboxylic acids and bromate.

Ultra-violet Irradiation

Ultra-violet irradiation (UV), which is present in sunlight, can kill bacteria, cysts and viruses if applied appropriately. Ultra-violet lamps concentrate UV onto a stream of water and the UV kills microbes. The raw water quality will greatly determine the effectiveness of the UV process. Turbidity or colour blocks UV penetration, thus preventing the light from penetrating through to the microbes. Recent research has demonstrated that low and medium pressure UV systems are able to kill cryptosporidium and, likely, giardia cysts at dosages that are cost-competitive with chlorination. The development of a reliable technology is expected. Since UV treatment does not provide a disinfectant residual, chlorine or other disinfectant must be added after disinfection with UV in order to provide a residual which can be maintained throughout the distribution system.

GLOSSARY

Aerobic Bacteria - bacteria that require oxygen for growth and can grow under an air atmosphere (21% oxygen).

Aesthetic - aspects of drinking water quality (namely taste, odour, colour and clarity) that are perceivable by the senses.

Aggressive Water - having a tendency to corrode. Dissolved oxygen, pH, alkalinity, calcium, suspended solids, total salt concentration etc. all have different effects on the corrosion of different metals.

Algae - simple chlorophyll-bearing plants, most of which are aquatic and microscopic in size.

Alkalinity - measure of a water's ability to neutralize acid; generally made up of bicarbonate and carbonate ions.

Alpha particle - a charged particle emitted from the nucleus of an atom and having a mass and charge identicalto a helium nucleus. Gross alpha particle activity is the total radioactivity from alpha particle emission as inferred from measurements on a dry sample.

Anaerobic bacteria - bacteria that do not use oxygen to obtain energy and cannot grow under an air atmosphere.

Antiseptic - a substance used to destroy or prevent the growth of infectious microorganisms on or in the body.

Bacteria - a group of diverse and ubiquitous procaryotic single-celled organisms.

Becquerel (Bq) - unit of radioactivity which expresses the rate of disintegration of a radionuclide; one becquerel equals one nuclear transformation per second and corresponds to approximately 27 picocuries.

Beta particle - a charged particle emitted from the nucleus of an atom with the mass and charge of an electron. Gross beta particle activity is the total radioactivity resulting from beta particle emission as inferred from measurements on a dry sample.

Biocide - a substance that kills all living organisms, pathogenic or non-pathogenic.

Biofilm - microbial cells attach to pipe surfaces and multiply to form a film or slime layer on the pipe which can harbour and protect coliform bacteria from disinfectants.

Carcinogen - parameter for which the evidence from studies indicates that there is a causal relationship between exposure and occurrence of cancer, whether in animals or humans.

Cholinesterase - an esterase (enzyme) present in all body tissues which hydrolyses acetylcholine into choline and acetic acid. Acetylcholine affects nerve impulse transmissions therefore substances that impair the function of cholinesterase enzymes are neurotoxic.

Carbamate - a salt or ester of carbamic acid.

Coagulation - in water treatment a process where chemicals are added to destabilize or entrap suspended and colloidal particles to allow formation of rapidly settling aggregates.

Colloid - particulate or insoluble material in a finely divided form that remains dispersed in a liquid for an extended time period.

Conventional Filtration - a mode of water treatment to remove particles which consists of coagulant addition, rapid mixing, coagulation, flocculation, sedimentation and filtration.

Contamination - the introduction of materials which makes otherwise potable water unfit or less acceptable for use.

Corrosion - in the context of drinking water distribution, corrosion is the deterioration and leaching of metal from a pipe surface as a result of its reaction with the aquatic environment.

Cryptosporidium - a protozoan parasite that produces an environmentally stable oocyst that is highly resistant to disinfection, but can be removed by effective treatment, which includes filtration.

Desiccant - a drying agent capable of absorbing moisture from the atmosphere in a small enclosure.

Detoxification - the process of removing or neutralizing a poison.

Diatomaceous Earth - a fine, siliceous material composed mainly of the skeletal remains of diatoms, a free-floating microscopic plant found in the ocean.

Diatomaceous Earth Filtration - a filtration process capable of substantial particle removal, in which (1) a "precoat" cake of diatomaceous earth filter media is deposited on a support membrane(septum) and (2) while the water is filtered by passing through the cake on the septum, additional media, known as "body feed" , is continuously added to the feed water to maintain the permeability of the filter cake.

Direct Filtration - a mode of water treatment to remove particles which consists of coagulant addition, rapid mixing, coagulation, minimal flocculation, and filtration. The flocculation facilities may be omitted , while the sedimentation process is always omitted.

Disinfection - effective destruction by chemical or physical processes of non-spore forming organisms capable of causing disease. Spore forming bacteria and parasitic cysts are usually resistant to traditional methods of disinfection.

Ectoparasite - a parasite that lives on the surface of the host body.

Filter - a porous media through which a liquid may be passed to effect removal of suspended materials.

Flocculation - the process by which suspended, colloidal or very fine particles coalesce and agglomerate to form larger particles of sufficient size to settle readily.

Fumigant - a chemical compound which acts in the gaseous state to destroy insects and their larvae and other pests.

Fungi - a group of diverse and widespread unicellular and multicellular eucaryotic microorganisms.

Gastrointestinal disturbances - disturbances related to the portion of the digestive system including the stomach, intestine, and all accessory organs.

Gamma Radiation - short wavelength electromagnetic radiation emitted from the atomic nucleus.

Giardia - small, flagellated, protozoan parasites that inhabit the small intestines of a variety of animals. Giardia is the most commonly reported intestinal parasite in North America causing nausea, diarrhoea, an uneasiness in the upper intestine, malaise and perhaps low-grade fevers and chills. A well-managed water treatment system providing effective filtration and disinfection should control contamination by *Giardia*.

Gram-negative - referring to bacteria not holding the colour of the primary stain when treated by the Gram staining procedure.

Ground water - water located in the saturated zone of the earth's crust.

Herbicide - chemical agent that destroys or inhibits plant growth.

Humic Matter - major constituents of soil caused by decaying vegetation; the dissolved organic colouring material in water is almost totally made up of humic matter. Humic matter is divided into two classifications on the basis of their solubilities: humic and fulvic acids.

Hydroxybenzonitrile - an organic liquid with an almond colour.

Incrustation - deposition of a crust or hard coating on a surface.

Insecticide - any chemical or natural agent that kills insects.

Larvicide - an agent that kills larvae.

Macroorganism - aquatic organism that can be seen without the aid of a microscope, and can include copepod, cladoceran, oligochaete, mollusca and aquatic insects.

Membrane Filter (MF) - a method for the enumeration of bacteria in water. A measured volume of water is filtered through a sterilized membrane which is then transferred to the surface of an appropriate agar

medium and incubated. Upon incubation, retained bacteria give rise to visible colonies on the membrane surface.

Methaemoglobinaemia - a condition caused by the presence in the blood of methaemoglobin, an altered haemoglobin which is unable to transport oxygen.

Microorganism - a microscopic organism that cannot be seen without the aid of a microscope, including bacteria, protozoa, fungi, viruses and algae.

Most Probable Number (MPN) - a method for statistically estimating the number of bacteria in water. It is not an actual count of the bacteria.

Nematode - member of the class Nematoda, the roundworms, some of which are parasites. Free-living nematodes are abundant in soil and water.

Non-point Source - discharge of pollutants which cannot be traced back to a specific source, for example agricultural or urban run-off.

NTU (Nephelometric Turbidity Unit) - Unit of measure for turbidity in a water sample.

Occupational exposure - exposure to a parameter at the workplace.

Organochlorine - an organic compound containing one or more chlorine atoms.

Organophosphorus - an organic compound containing one or more phosphate groups.

Oxidase-positive - the presence, in bacteria, of the cytochrome c oxidase enzyme.

Oxidize - a process where the loss of electrons or hydrogen atoms or the combination with oxygen occurs.

Parameter - measurable or quantifiable characteristic or feature.

Parasite - an organism that lives on or in the body of another from which it obtains its nutrients.

Pathogen - an organism capable of eliciting disease symptoms in another organism.

Pediculicide - an agent used to destroy lice.

Pesticide - a chemical or mixture of chemicals used to kill unwanted species of plants or animals.

pH - index of hydrogen ion activity, pH is defined as the negative logarithm of hydrogen ion concentration in moles per litre. A solution of pH from 0 to less than 7 is acid, pH of 7 is neutral, pH from above 7 to 14 is alkaline.

Phenol - an organic chemical with a sharp burning taste, used to make a variety of other organic chemicals, resins, and as a solvent and chemical intermediate.

Picocurie - 10^{-12} curies (a curie is the unit of radioactivity contained in any quantity of material yielding 3.7 x 10^{-10} radioactive disintegrations per second).

Pollution (water) - causing or inducing objectionable conditions in any watercourse and affecting adversely the environment and use or uses to which the water thereof may be put.

Polynuclear hydrocarbon - organic chemical hydrocarbon molecule with two or more nuclei, e.g. naphthalene.

Potable Water - water fit for human consumption.

Precipitate - to separate in solid particles from a liquid as the result of a chemical or physical change.

Presence/Absence (P/A) Test - a qualitative procedure used to determine the presence or absence of coliforms in water.

Protozoa - unicellular, non-photosynthetic, nucleated organisms, such as amoeba, ciliates and flagellates.

Raw Water - surface or ground water that is available as a source of drinking water but has not received any treatment.

Radioactive - capable of emitting radioactivity, the spontaneous nuclear disintegration with emission of corpuscular or electromagnetic radiation or both.

Radionuclide - any man-made or natural element which emits radiation in the form of alpha or beta particles or as gamma rays.

Sanitary Survey - survey and analysis of the physical environment for the purpose of identifying existing and potential sources of health hazards and environmental contamination.

Scabicide - an agent lethal to itch mites.

Sedimentation - a water treatment process in which solid particles settle out of the water being treated in a clarifier or sedimentation basin.

Slow Sand Filtration - a water treatment process involving passage of raw water through a bed of sand at low velocity (less than 0.4 m/h) resulting in substantial particle removal by physical and biological mechanisms.

Spore - a reproductive unit lacking a preformed embryo that is capable of germinating directly to form a new individual. A resistant body formed by certain microorganisms; a resistant resting cell; a primitive unicellular reproductive body.

Surface Water - water that rests upon the earth's surface.

TCU (True Colour Units) - the measurement of colour using the platinum cobalt scale. The colour of water resulting from parameters which are totally in solution not to be mistaken for apparent colour resulting from colloidal or suspended matter.

Toxicological - relating to the study of poisons, including their nature, effects, and detection, and methods of treatment.

Triazine - an organic heterocyclic compound containing a six-member ring formed from carbon and containing three nitrogen atoms.

Trivalent - having a valency of three.

Urea - the major end product of nitrogen excretion in mammals or the synthesis of industrial ammonia and carbon dioxide used as a source of non-protein nitrogen for ruminant livestock, and as a nitrogen fertilizer.

Virus - group of sub-microscopic agents that infect plants and animals, usually manifesting their presence by causing disease, and are unable to multiply outside the host tissues.

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PROCEDURE B13-3 CHLORINATION OF POTABLE WATER SUPPLIES IN ONTARIO

1.0 RATIONALE

Procedure B13-3 is a supporting document for the Ontario Drinking Water Protection Regulation. Procedure B13-3 supersedes the MOE Bulletin 65-W-4 "Chlorination of Potable Water Supplies" 1987.

Disinfection, the destruction or inactivation of pathogenic organisms, is the most important step in any water treatment process. New microbiological challenges and increased knowledge of disinfection by-products makes it essential that the design of new waterworks, the upgrading of, or extension to, existing waterworks and the maintenance of existing facilities reflect current knowledge, technologies and practices.

1.1 GOALS

Disinfection in Ontario is primarily accomplished through chlorination. This Procedure provides guidance for the use of chlorine for disinfection. The goals are:

- minimize the risk to human health attributable to disease causing microorganisms that may be present in the drinking water supply;
- achieve and maintain adequate disinfection of a ground or surface water supply at the water treatment plant, while minimizing disinfection by-product concentrations in the treated water; and
- outline the requirements to achieve adequate disinfection of water distribution systems.

2.0 CHLORINATION REQUIREMENTS FOR WATER WORKS

2.1 GROUNDWATER SUPPLIES

a. A minimum chlorine residual, measured as free chlorine, after 15 minutes contact time determined as T_{10}[1] at maximum flow and before the first consumer of 0.2 mg/L should be maintained in all disinfected water entering the distribution system.

b. Where a groundwater source is determined to be under the direct influence of surface water; and where the source water quality conditions are suitable to avoid filtration as determined by the Ministry; and where there is adequate watershed control to avoid filtration as determined by the Ministry; the system treatment requirements of greater than 3 log reduction of giardia lamblia cysts and greater than 4 log reduction of viruses may be achieved by disinfection only, in accordance with Section 3 of this document.

c. A maximum chlorine residual, measured as free chlorine should be less than 4.0 mg/L, or as combined chlorine should be less than 3.0 mg/L at all times, at any location, in the water distribution system.

d. A minimum free chlorine residual in a water distribution system should be 0.2 mg/L. Minimum combined chlorine residuals, if appropriate, should be 1.0 mg/L at distant points in the distribution system.

[1] T_{10} is the time for 10% of the water (tracer) to pass through the unit (i.e. clearwell). T_{10} values can be significantly different from calculated detention times (T) and shall be determined by a tracer study or mathematical modeling or by reference to typical baffling conditions.

e. Automatic chlorine residual recorders should be provided where the chlorine demand varies appreciably over a short period of time. The installation of an alarm system should be provided to ensure continuous disinfection at all waterworks.

f. Monitor chlorine residuals according to the Ontario Drinking Water Standards and/or site specific Certificate of Approval requirements using monitoring equipment capable of measuring chlorine residuals with an accuracy of +/-0.1 mg/L.

g. Disinfect all new water mains and water mains taken out of service for inspection, repair or other activities that may lead to contamination before they are placed in service according to the provisions of the AWWA C651-99 Standard for Disinfecting Water Mains, AWWA C652-92 for storage facilities, C653-97 for Water Treatment Plants and C654-97 for Wells or a proven equivalent procedure.

2.2 SURFACE WATER SUPPLIES

a. Achieve, through a combination of filtration and continuous disinfection, a minimum3-log removal/inactivation of giardia cysts and a 4-log removal/inactivation of viruses at all times at or before the first consumers' connection in accordance with Section 3 of this document. Higher removal/inactivation credits may be required for source waters where increased levels of raw water contamination may occur.

b. A minimum free chlorine residual in a water distribution system should be 0.2 mg/L. Minimum combined chlorine residuals, if appropriate, should be 1.0 mg/L at distant points in the distribution system.

c. A maximum chlorine residual, measured as free chlorine should be less than 4.0 mg/L, or as combined chlorine should be less than 3.0 mg/L at all times at any location in the water distribution system.

d. The installation of continuous residual analyzers equipped with a high and low residual alarm system should be provided to ensure continuous disinfection at all waterworks, particularly at remotely operated or minimally supervised facilities. Automatic chlorine residual recorders should be provided where the chlorine demand varies appreciably over a short period of time.

e. Monitor chlorine residuals according to the Ontario Drinking Water Standards and/or site specific Certificate of Approval requirements using metering equipment capable of measuring chlorine residuals with an accuracy of +/- 0.1 mg/L.

f. Disinfect all new water mains and water mains taken out of service for inspection, repair or other activities that may lead to contamination before they are placed in service according to the provisions of the AWWA C651-99 Standard for Disinfecting Water Mains, AWWA C652-92 for storage facilities, C653-97 for Water Treatment Plants and C654-97 for Wells or a proven equivalent procedure.

3.0 "CT" DISINFECTION CONCEPT

This section outlines the CT disinfection concept, developed by the United States Environmental Protection Agency (Federal Register, 40 CFR, Parts 141 and 142, June 29, 1989). The CT concept uses the combination of disinfection residual concentration (mg/L) and the effective disinfection contact time (in minutes) to measure the effective pathogen reduction achieved in a water works.

a. The required log reductions of pathogens are achieved by a combination of filtration and disinfection removal/inactivation credits.

   Disinfection shall contribute a minimum of 0.5 log giardia cyst inactivation or 2 log virus inactivation to the total credits.

The following table summarizes the credits attributed to typical physical treatment processes.

Treatment	Giardia Cysts	Viruses
Conventional filtration	2.5 log	2.0 log
Direct Filtration	2.0 log	1.0 log
Slow Sand Filtration	2.0 log	2.0 log

Credits for membrane filtration will be considered on a site specific basis.

b. Required CT values are affected by pH, chlorine residual concentration and temperature. These CT values are determined by referring to the standard tables of required CT's in the "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water systems Using Surface Water Sources." (CT values for inactivation of giardia cysts viruses by free chlorine are included in Appendix A).

c. Disinfection CT values for the waterworks are calculated by multiplying the disinfection residual concentration (mg/L) by the effective disinfection contact time (in minutes).

$$CT = \text{Concentration (mg/L)} \times \text{Time (minutes)}$$

The chlorine residual is measured at the end of each treatment process (i.e. clarification) and the contact time used is T_{10} - time for 10% of the water to pass through that process. The use of T_{10} ensures that 90% of the water will be better treated than the minimum.

Actual T_{10} values can be significantly different from calculated hydraulic detention times (T) and should be determined by a tracer study or by reference to typical baffling conditions. The following table summarizes typical baffling conditions.

TYPICAL BAFFLING CONDITIONS

Baffling Condition	T_{10}/T Ratio	Baffling Description
Unbaffled (mixed flow) separate inlet/outlet	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet or outlet with some intra-basin baffles
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders
Perfect (plug flow)	1	Very high length to width ratio (pipeline flow)

d. CT values can be calculated for each unit process of the treatment train and summed. The total (Calculated) CT values are then compared to the Required CT values.

Calculated CT values should be, at all times during plant operation, be equal to or greater than the Required CT values for a recorded pH, temperature and chlorine residual concentration.

e. Total credits for the treatment plant are calculated by summing up the credits for each process unit train.

4.0 ALTERNATIVE DISINFECTANTS

Some owners of waterworks may need to address other water quality issues such as taste and odour or disinfection by-products while maintaining adequate disinfection. To meet this challenge the use of disinfectants such as ozone, chloramines, chlorine dioxide and ultraviolet radiation is increasing in Ontario.

The application of alternative disinfectants is acceptable provided that the formation of disinfection by-products is minimized and the alternate disinfectant has been shown to achieve the level of disinfection that is required with chlorination. Notwithstanding the use of alternative disinfectants as the primary disinfectant, it will be necessary to maintain a chlorine residual throughout the distribution system.

TABLE I

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 0.5°C OR LOWER

Free Chlorine Concentration mg/L	pH <= 6 Log Inactivations						pH = 6.5 Log Inactivations						pH = 7.0 Log Inactivations						pH = 7.5 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	23	46	69	91	114	137	27	54	82	109	136	163	33	65	98	130	163	195	40	79	119	158	198	237
0.6	24	47	71	94	118	141	28	56	84	112	140	168	33	67	100	133	167	200	40	80	120	159	199	239
0.8	24	48	73	97	121	145	29	57	86	115	143	172	34	68	103	137	171	205	41	82	123	164	205	246
1	25	49	74	99	123	148	29	59	88	117	147	176	35	70	105	140	175	210	42	84	127	169	211	253
1.2	25	51	76	101	127	152	30	60	90	120	150	180	36	72	108	143	179	215	43	86	130	173	216	259
1.4	26	52	78	103	129	155	31	61	92	123	153	184	37	74	111	147	184	201	44	89	133	177	222	266
1.6	26	52	79	105	131	157	32	63	95	126	158	189	38	75	113	151	188	226	46	91	137	182	228	273
1.8	27	54	81	108	135	162	32	64	97	129	161	193	39	77	116	154	193	231	47	93	140	186	233	279
2	28	55	83	110	138	165	33	66	99	131	164	197	39	79	118	157	197	236	48	95	143	191	238	286
2.2	28	56	85	113	141	169	34	67	101	134	168	201	40	81	121	161	202	242	50	99	149	198	248	297
2.4	29	57	86	115	143	172	34	68	103	137	171	205	41	82	124	165	206	247	50	99	149	199	248	298
2.6	29	58	88	117	146	175	35	70	105	139	174	209	42	84	126	168	210	252	51	101	152	203	253	304
2.8	30	59	89	119	148	178	36	71	107	142	178	213	43	86	129	171	214	257	52	103	155	207	258	310
3	30	60	91	121	151	181	36	72	109	145	181	217	44	87	131	174	218	261	53	105	158	211	263	316

Free Chlorine Concentration mg/L	pH = 8.0 Log Inactivations						pH = 8.5 Log Inactivations						pH <= 9.0 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	46	92	139	185	231	277	55	110	165	219	274	329	65	130	195	260	325	390
0.6	48	95	143	191	238	286	57	114	171	228	285	342	68	136	204	271	339	407
0.8	49	98	148	197	246	295	59	118	177	236	295	354	70	141	211	281	352	422
1	51	101	152	203	253	304	61	122	183	243	304	365	73	146	219	291	364	437
1.2	52	104	157	209	261	313	63	125	188	251	313	376	75	150	226	301	376	451
1.4	54	107	161	214	268	321	65	129	194	258	323	387	77	155	232	309	387	464
1.6	55	110	165	219	274	329	66	132	199	265	331	397	80	159	239	318	398	477
1.8	56	113	169	225	282	338	68	136	204	271	339	407	82	163	245	326	408	489
2	58	115	173	231	288	346	70	139	209	278	348	417	83	167	250	333	417	500
2.2	59	118	177	235	294	353	71	142	213	284	355	426	85	170	256	341	426	511
2.4	60	120	181	241	301	361	73	145	218	290	363	435	87	174	261	348	435	522
2.6	61	123	184	245	307	368	74	148	222	296	370	444	89	178	267	355	444	533
2.8	63	125	188	250	313	375	75	151	226	301	377	452	91	181	272	362	451	543
3	64	127	191	255	318	382	77	153	230	307	383	460	92	184	276	368	460	552

TABLE 2

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 5° C

Free Chlorine Concentration mg/L	pH <= 6 Log Inactivations						pH = 6.5 Log Inactivations						pH = 7.0 Log Inactivations						pH = 7.5 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
<= 0.4	16	32	49	65	81	97	20	39	59	78	98	117	23	46	70	93	116	139	28	55	83	111	138	166
0.6	17	33	50	67	83	100	20	40	60	80	100	120	24	48	72	95	119	143	29	57	86	114	143	171
0.8	17	34	52	69	86	103	20	41	61	81	102	122	24	49	73	97	122	146	29	58	88	117	146	175
1	18	35	53	70	88	105	21	42	63	83	104	125	25	50	75	99	124	149	30	60	90	119	149	179
1.2	18	36	54	71	89	107	21	42	64	85	106	127	25	51	76	101	127	152	31	61	92	122	153	183
1.4	18	36	55	73	91	109	22	43	65	87	108	130	26	52	78	103	129	155	31	62	94	125	156	187
1.6	19	37	56	74	93	111	22	44	66	88	110	132	26	53	79	105	132	158	32	64	96	128	160	192
1.8	19	38	57	76	95	114	23	45	68	90	113	135	27	54	81	108	135	162	33	65	98	131	163	196
2	19	39	58	77	97	116	23	46	69	92	115	138	28	55	83	110	138	165	33	67	100	133	167	200
2.2	20	39	59	79	98	118	23	47	70	93	117	140	28	56	85	113	141	169	34	68	102	136	170	204
2.4	20	40	60	80	100	120	24	48	72	95	119	143	29	57	86	115	143	172	35	70	105	139	174	209
2.6	20	41	61	81	102	122	24	49	73	97	122	146	29	58	88	117	146	175	36	71	107	142	178	213
2.8	21	41	62	83	103	124	25	49	74	99	123	148	30	59	89	119	148	178	36	72	109	145	181	217
3	21	42	63	84	105	126	25	50	76	101	126	151	30	61	91	121	152	182	37	74	111	147	184	221

Free Chlorine Concentration mg/L	pH = 8.0 Log Inactivations						pH = 8.5 Log Inactivations						pH <= 9.0 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	33	66	99	132	165	198	39	79	118	157	197	236	47	93	140	186	233	279
0.6	34	68	102	136	170	204	41	81	122	163	203	244	49	97	146	194	243	291
0.8	35	70	105	140	175	210	42	84	126	168	210	252	50	100	151	201	251	301
1	36	72	108	144	180	216	43	87	130	173	217	260	52	104	156	208	260	312
1.2	37	74	111	147	184	221	45	89	134	178	223	267	53	107	160	213	267	320
1.4	38	76	114	151	189	227	46	91	137	183	228	274	55	110	165	219	274	329
1.6	39	77	116	155	193	232	47	94	141	187	234	281	56	112	169	225	281	337
1.8	40	79	119	159	198	238	48	96	144	191	239	287	58	115	173	230	288	345
2	41	81	122	162	203	243	49	98	147	196	245	294	59	118	177	235	294	353
2.2	41	83	124	165	207	248	50	100	150	200	250	300	60	120	181	241	301	361
2.4	42	84	127	169	211	253	51	102	153	204	255	306	61	123	184	245	307	368
2.6	43	86	129	172	215	258	52	104	156	208	260	312	63	125	188	250	313	375
2.8	44	88	132	175	219	263	53	106	159	212	265	318	64	127	191	255	318	382
3	45	89	134	179	223	268	54	108	162	216	270	324	65	130	195	259	324	389

TABLE 3
CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 10 °C

Free Chlorine Concentration mg/L	pH <= 6 Log Inactivations						pH = 6.5 Log Inactivations						pH = 7.0 Log Inactivations						pH = 7.5 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
<= 0.4	12	24	37	49	61	73	15	29	44	59	73	88	17	35	52	69	87	104	21	42	63	83	104	125
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	36	54	71	89	107	21	43	64	85	107	128
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131
1	13	26	40	53	66	79	16	31	47	63	78	94	19	37	56	75	93	112	22	45	67	89	112	134
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	38	57	76	95	114	23	46	69	91	114	137
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	39	58	77	97	116	23	47	70	93	117	140
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	96	120	144
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	41	61	81	102	122	25	49	74	98	123	147
2	15	29	44	58	73	87	17	35	52	69	87	104	21	41	62	83	103	124	25	50	75	100	125	150
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	64	85	106	127	26	51	77	102	128	153
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	65	86	108	129	26	52	79	105	131	157
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131	27	53	80	107	133	160
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	67	89	112	134	27	54	82	109	136	163
3	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137	28	55	83	111	138	166

Free Chlorine Concentration mg/L	pH = 8.0 Log Inactivations						pH = 8.5 Log Inactivations						pH <= 9.0 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	25	50	75	99	124	149	30	59	89	118	148	177	35	70	105	139	174	209
0.6	26	51	77	102	128	153	31	61	92	122	153	183	36	73	109	145	182	218
0.8	26	53	79	105	132	158	32	63	95	126	158	189	38	75	113	151	188	226
1	27	54	81	108	135	162	33	65	98	130	163	195	39	78	117	156	195	234
1.2	28	55	83	111	138	166	33	67	100	133	167	200	40	80	120	160	200	240
1.4	28	57	85	113	142	170	34	69	103	137	172	206	41	82	124	165	206	247
1.6	29	58	87	116	145	174	35	70	106	141	176	211	42	84	127	169	211	253
1.8	30	60	90	119	149	179	36	72	108	143	179	215	43	86	130	173	216	259
2	30	61	91	121	152	182	37	74	111	147	184	221	44	88	133	177	221	265
2.2	31	62	93	124	155	186	38	75	113	150	188	225	45	90	136	181	226	271
2.4	32	63	95	127	158	190	38	77	115	153	192	230	46	92	138	184	230	276
2.6	32	65	97	129	162	194	39	78	117	156	195	234	47	94	141	187	234	281
2.8	33	66	99	131	164	197	40	80	120	159	199	239	48	96	144	191	239	287
3	34	67	101	134	168	201	41	81	122	162	203	243	49	97	146	195	243	292

TABLE 4

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 15°C

Free Chlorine Concentration mg/L	pH <= 6 Log Inactivations						pH = 6.5 Log Inactivations						pH = 7.0 Log Inactivations						pH = 7.5 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	8	16	25	33	41	49	10	20	30	39	49	59	12	23	35	47	58	70	14	28	42	55	69	83
0.6	8	17	25	33	42	50	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
0.8	9	17	26	35	43	52	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88
1	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75	15	30	45	60	75	90
1.2	9	18	27	36	45	54	11	21	32	43	53	64	13	25	38	51	63	76	15	31	46	61	77	92
1.4	9	18	28	37	46	55	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
1.6	10	19	28	37	47	56	11	22	33	44	55	66	13	26	40	53	66	79	16	32	48	64	80	96
1.8	10	19	29	38	48	57	11	23	34	45	57	68	14	27	41	54	68	81	16	33	49	65	82	98
2	10	19	29	39	48	58	12	23	35	46	58	69	14	28	42	55	69	83	17	33	50	67	83	100
2.2	10	20	30	39	49	59	12	23	35	47	58	70	14	28	43	57	71	85	17	34	51	68	85	102
2.4	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86	18	35	53	70	88	105
2.6	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88	18	36	54	71	89	107
2.8	10	21	31	41	52	62	12	25	37	49	62	74	15	30	45	59	74	89	18	36	55	73	91	109
3	11	21	32	42	53	63	13	25	38	51	63	76	15	30	46	61	76	91	19	37	56	74	93	111

Free Chlorine Concentration mg/L	pH = 8.0 Log Inactivations						pH = 8.5 Log Inactivations						pH <= 9.0 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	17	33	50	66	83	99	20	39	59	79	98	118	23	47	70	93	117	140
0.6	17	34	51	68	85	102	20	41	61	81	102	122	24	49	73	97	122	146
0.8	18	35	53	70	88	105	21	42	63	84	105	126	25	50	76	101	126	151
1	18	36	54	72	90	108	22	43	65	87	108	130	26	52	78	104	130	156
1.2	19	37	56	74	93	111	22	45	67	89	112	134	27	53	80	107	133	160
1.4	19	38	57	76	95	114	23	46	69	91	114	137	28	55	83	110	138	165
1.6	19	39	58	77	97	116	24	47	71	94	118	141	28	56	85	113	141	169
1.8	20	40	60	79	99	119	24	48	72	96	120	144	29	58	87	115	144	173
2	20	41	61	81	102	122	25	49	74	98	123	147	30	59	89	118	148	177
2.2	21	41	62	83	103	124	25	50	75	100	125	150	30	60	91	121	151	181
2.4	21	42	64	85	106	127	26	51	77	102	128	153	31	61	92	123	153	184
2.6	22	43	65	86	108	129	26	52	78	104	130	156	31	63	94	125	157	188
2.8	22	44	66	88	110	132	27	53	80	106	133	159	32	64	96	127	159	191
3	22	45	67	89	112	134	27	54	81	108	135	162	33	65	98	130	163	195

TABLE 5
CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 20°C

Free Chlorine Concentration mg/l	pH <= 6 Log Inactivations						pH = 6.5 Log Inactivations						pH = 7.0 Log Inactivations						pH = 7.5 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	6	12	18	24	30	36	7	15	22	29	37	44	9	17	26	35	43	52	10	21	31	41	52	62
0.6	6	13	19	25	32	38	8	15	23	30	38	45	9	18	27	36	45	54	11	21	32	43	53	64
0.8	7	13	20	26	33	39	8	15	23	31	38	46	9	18	28	37	46	55	11	22	33	44	55	66
1	7	13	20	26	33	39	8	16	24	31	39	47	9	19	28	37	47	56	11	22	34	45	56	67
1.2	7	13	20	27	33	40	8	16	24	32	40	48	10	19	29	38	48	57	12	23	35	46	58	69
1.4	7	14	21	27	34	41	8	16	25	33	41	49	10	19	29	39	48	58	12	23	35	47	58	70
1.6	7	14	21	28	35	42	8	17	25	33	42	50	10	20	30	39	49	59	12	24	36	48	60	72
1.8	7	14	22	29	36	43	9	17	26	34	43	51	10	20	31	41	51	61	12	25	37	49	62	74
2	7	15	22	29	37	44	9	17	26	35	43	52	10	21	31	41	52	62	13	25	38	50	63	75
2.2	7	15	22	29	37	44	9	18	27	35	44	53	11	21	32	42	53	63	13	26	39	51	64	77
2.4	8	15	23	30	38	45	9	18	27	36	45	54	11	22	33	43	54	65	13	26	39	52	65	78
2.6	8	15	23	31	38	46	9	18	28	37	46	55	11	22	33	44	55	66	13	27	40	53	67	80
2.8	8	16	24	31	39	47	9	19	28	37	47	56	11	22	34	45	56	67	14	27	41	54	68	81
3	8	16	24	31	39	47	10	19	29	38	48	57	11	23	34	45	57	68	14	28	42	55	69	83

Free Chlorine Concentration mg/L	pH = 8.0 Log Inactivations						pH = 8.5 Log Inactivations						pH <= 9.0 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	12	25	37	49	62	74	15	30	45	59	74	89	18	35	53	70	88	105
0.6	13	26	39	51	64	77	15	31	46	61	77	92	18	36	55	73	91	109
0.8	13	26	40	53	66	79	16	32	48	63	79	95	19	38	57	75	94	113
1	14	27	41	54	68	81	16	33	49	65	82	98	20	39	59	78	98	117
1.2	14	28	42	55	69	83	17	33	50	67	83	100	20	40	60	80	100	120
1.4	14	28	43	57	71	85	17	34	52	69	86	103	21	41	62	82	103	123
1.6	15	29	44	58	73	87	18	35	53	70	88	105	21	42	63	84	105	126
1.8	15	30	45	59	74	89	18	36	54	72	90	108	22	43	65	86	108	129
2	15	30	46	61	76	91	18	37	55	73	92	110	22	44	66	88	110	132
2.2	16	31	47	62	78	93	19	38	57	75	94	113	23	45	68	90	113	135
2.4	16	32	48	63	79	95	19	38	58	77	96	115	23	46	69	92	115	138
2.6	16	32	49	65	81	97	20	39	59	78	98	117	24	47	71	94	118	141
2.8	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	95	119	143
3	17	34	51	67	84	101	20	41	61	81	102	122	24	49	73	97	122	146

TABLE 6

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 25° C

Free Chlorine Concentration mg/L	pH <= 6 Log Inactivations						pH = 6.5 Log Inactivations						pH = 7.0 Log Inactivations						pH = 7.5 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
0.4	4	8	12	16	20	24	5	10	15	19	24	29	6	12	18	23	29	35	7	14	21	28	35	42
0.6	4	8	13	17	21	25	5	10	15	20	25	30	6	12	18	24	30	36	7	14	22	29	36	43
0.8	4	9	13	17	22	26	5	10	16	21	26	31	6	12	19	25	31	37	7	15	22	29	37	44
1	4	9	13	17	22	26	5	10	16	21	26	31	6	12	19	25	31	37	8	15	23	30	38	45
1.2	5	9	14	18	23	27	5	11	16	21	27	32	6	13	19	25	32	38	8	15	23	31	38	46
1.4	5	9	14	18	23	27	6	11	17	22	28	33	7	13	20	26	33	39	8	16	24	31	39	47
1.6	5	9	14	19	23	28	6	11	17	22	28	33	7	13	20	27	33	40	8	16	24	32	40	48
1.8	5	10	15	19	24	29	6	11	17	23	28	34	7	14	21	27	34	41	8	16	25	33	41	49
2	5	10	15	19	24	29	6	12	18	23	29	35	7	14	21	27	34	41	8	17	25	33	42	50
2.2	5	10	15	20	25	30	6	12	18	23	29	35	7	14	21	28	35	42	9	17	26	34	43	51
2.4	5	10	15	20	25	30	6	12	18	24	30	36	7	14	22	29	36	43	9	17	26	35	43	52
2.6	5	10	16	21	26	31	6	12	19	25	31	37	7	15	22	29	37	44	9	18	27	35	44	53
2.8	5	10	16	21	26	31	6	12	19	25	31	37	8	15	23	30	38	45	9	18	27	36	45	54
3	5	11	16	21	27	32	6	13	19	25	32	38	8	15	23	31	38	46	9	18	28	37	46	55

Free Chlorine Concentration mg/L	pH = 8.0 Log Inactivations						pH = 8.5 Log Inactivations						pH <= 9.0 Log Inactivations					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
<= 0.4	8	17	25	33	42	50	10	20	30	39	49	59	12	23	35	47	58	70
0.6	9	17	26	34	43	51	10	20	31	41	51	61	12	24	37	49	61	73
0.8	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75
1	9	18	27	36	45	54	11	22	33	43	54	65	13	26	39	52	65	78
1.2	9	18	28	37	46	55	11	22	34	45	56	67	13	27	40	53	67	80
1.4	10	19	29	38	48	57	12	23	35	46	58	69	14	27	41	55	68	82
1.6	10	19	29	39	48	58	12	23	35	47	58	70	14	28	42	56	70	84
1.8	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
2	10	20	31	41	51	61	12	25	37	49	62	74	15	29	44	59	73	88
2.2	10	21	31	41	52	62	13	25	38	50	63	75	15	30	45	60	75	90
2.4	11	21	32	42	53	63	13	26	39	51	64	77	15	31	46	61	77	92
2.6	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
2.8	11	22	33	44	55	66	14	27	40	53	67	80	16	32	48	64	80	96
3	11	22	34	45	56	67	14	27	41	54	68	81	16	32	49	65	81	97

TABLE 7
CT VALUES FOR INACTIVATION OF VIRUSES BY FREE CHLORINE

Temperature °C	Log Inactivation					
	2		3		4	
	pH		pH		pH	
	6 to 9	10	6 to 9	10	6 to 9	10
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15